

GROUNDWATER IMPACT ASSESSMENT REPORT
OF THE EXISTING FACILITY

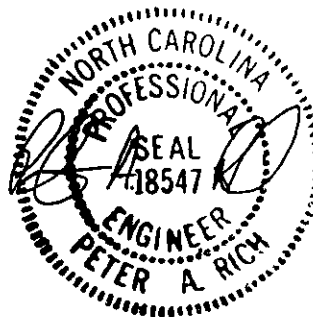
WINNEBAGO RECLAMATION LANDFILL
ROCKFORD, ILLINOIS

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1 INTRODUCTION

This report summarizes the approach and results of the Groundwater Impact Assessment (GIA) for the existing Winnebago Reclamation Landfill (WRL). The GIA was prepared as required by Title 35 Illinois Administrative Code (IAC) Section 814.104 (a). This report addresses the requirements of 35 IAC 811.317 and closely follows the specifications described in 35 IAC 812.316 and guidance documents (LPC-PA2) from the IEPA.

The report describes an integrated evaluation of the acceptability of the physical setting and design of the existing landfill unit. This evaluation was performed through an assessment of potential impacts of leachate seepage on groundwater quality as determined through contaminant transport modeling. Specifically, transport modeling was performed to demonstrate that a reduction of leachate head to two feet will lead to an acceptable groundwater impact in which concentrations of leachate constituents in groundwater are less than the Applicable Groundwater Quality Standards (AGQS) at and beyond the limit of the zone of attenuation for the 100-year period following closure of the landfill unit.

1.1 SITE BACKGROUND

The WRL landfill is located approximately five miles south of Rockford, Illinois in a predominantly rural unincorporated area (Figure 1.1). The site is located on a topographic high bounded by Kilbuck Creek to the west, Lindenwood Road to the east, and intermittent streams to the north and south (Plate 1). A 27.5 acre permitted expansion area, located just south of the existing unit, is currently under development. Located to the east and hydrogeologically upgradient of the WRL site is the ACME Solvents Superfund site.

The Winnebago Reclamation Landfill (Pagel Landfill) is an active municipal solid waste disposal facility constructed with an asphalt liner, and is equipped with leachate and gas collection systems. The liner is sloped approximately one to two percent from the east to the west and from the west to the east such that leachate collects in a landfill invert (LCM5)

in the western third of the landfill (Plate 1). Landfill operations began in 1972 at the 42.6-acre facility under Illinois Environmental Protection Agency (IEPA) permit number 1972-24. The active life of the existing landfill is approximately six years based on estimates of current landfilling rates.

Remedial measures, as required by the ROD and the Consent Decree, will be instituted to address impacted groundwater to the west of the landfill. Elevated constituent concentrations outside the zone of attenuation (ZOA) will be reduced by the following remedial measures: 1) installation of a final composite geomembrane cover; 2) installation and operation of a gas/leachate collection system; and 3) installation, operation, and monitoring of a groundwater remediation system. These remedial measures are discussed in greater detail below.

The source mass release rate to groundwater will be reduced by limiting infiltration through placement of a final cover, which will consist of a 12-inch layer of compacted clay ($K = 1 \times 10^{-6}$ cm/sec) overlain by a textured 30-mil VLDPE geomembrane. Overlying the geomembrane, a vegetated protective layer will be installed and will consist of an eight-inch granular drainage layer overlain by soil for a total layer thickness of 36 inches. The source mass release rate to groundwater will also be reduced by operation of dual-purpose gas/leachate extraction wells to reduce leachate head levels. The dual gas/leachate extraction wells will be installed approximately 200 feet apart on a rectangular grid throughout the landfill area. Existing impacted groundwater will be addressed by active groundwater remediation. The groundwater remedial system will implement air sparging and natural in-situ bioremediation technologies to address the impacted groundwater near the source and in the western portion of the site. Groundwater treatment of organic and inorganic compounds will involve volatilization, biodegradation and immobilization processes.

1.2 REPORT OBJECTIVE

This GIA report demonstrates an acceptable groundwater impact assessment by demonstrating that the concentrations of leachate constituents in groundwater are less than their respective AGQS values outside the limit of the zone of attenuation for the 100 year

period following closure of the landfill unit. The report includes a presentation of the: 1) site conceptual model; 2) translation of the conceptual model into a mathematical model; 3) transport model selection and reliability; and 4) model results and sensitivity analyses.

1.3 GROUNDWATER IMPACT ASSESSMENT APPROACH

Typically, a GIA simulates the operational period and a 100 year post-operational period. However, because WRS is performing a remedial action on existing impacted groundwater that exceeds AGQs, the GIA is directed toward assessing the potential impacts of WRL after completion of the remedial action, final cover placement, and leachate head reduction. Impacted groundwater at the WRL site is currently being addressed by a Consent Decree under the Comprehensive Environmental Responsibility Compensation and Liability Act (CERCLA). Remedial action design documents are being prepared for submission and approval to both the United States Environmental Protection Agency (USEPA) and Illinois Environmental Protection Agency (IEPA). The Consent Decree requires, at the end of the operating period, a final cover, gas extraction system, and leachate extraction system meeting the requirements of 35 IAC 811, and remediation of impacted groundwater.

Acceptability of the landfill design and setting will be demonstrated through groundwater flow and solute transport modeling. The GIA modeling utilized the analytical transient model AT123D (Yeh , 1981) to compute the spatial and temporal distribution of leachate constituents in the aquifer. Model input values were estimated from: 1) direct field measurements (i.e., hydraulic conductivity); 2) laboratory testing of liner materials; 3) calculations based on monitoring data (i.e., leachate seepage); and 4) conservatively based literature values. During remediation of existing impacted groundwater, the effect of installation of a low permeability cover and leachate removal will reduce leakage through the landfill liner by lowering the leachate head. Existing impacted groundwater is estimated to be cleaned up in five to 10 years (GeoTrans, 1995c). Based on HELP model calculations of infiltration rate through the final cover (Appendix A) and estimated leachate pumping rates, mass balance calculations (Appendix B) indicate that leachate heads can be reduced to two feet within approximately six years. The solute transport model evaluates the physical

setting and landfill design during the 100 year post-remediation time period in which leachate heads are reduced to two feet.

The reviewer and reader should note that this model representation of future conditions is inherently and intentionally conservative in order to conform to the IEPAs specifications and procedural requirements for GIAs. Consequently, although the model representation is based largely on site-specific measurements and test results, several of the underlying and simplified model assumptions are structured to yield worse than anticipated predictions.

The GIA Report includes a written evaluation and analysis that demonstrates and includes the following:

- Acceptability of Groundwater Impact;
- Model Input;
- Model Output;
- Maximum Allowable Predicted Concentrations (MAPCs).

Supporting documentation and data diskettes are included as appendices.

1.4 SUMMARY OF RESULTS

The GIA was performed to evaluate the acceptability of the landfill design and physical setting after: 1) installation of final cover; 2) reduction of leachate head to two feet; and 3) clean-up of existing impacted groundwater. Using a compilation of leachate constituents from previous leachate sampling events, a set of eight surrogate compounds were developed to represent all landfill leachate constituents. Conservative model assumptions and model parameter values were used to perform solute transport modeling. These conservative assumptions provide a greater confidence in the model parameters since there is a limited amount of uncertainty in the model parameters. Likewise, greater than anticipated concentrations are obtained through the use of conservative assumptions. In addition, use of conservative assumptions provides an analysis of the acceptability of the

landfill impacts using the worst possible scenario. Results of the solute transport modeling shows that all surrogate groups are below their AGQS for the 100 year post-remediation period. Sensitivity analyses were performed to examine the effects of uncertainty in model parameter values. Results of the sensitivity analysis also demonstrate an acceptable groundwater impact because even with variations in model parameters, surrogate groups are below their AGQS for the 100 year post-remediation period.

2 GROUNDWATER IMPACT ASSESSMENT

As stated above, the GIA provides a systematic method to assess the impacts of leachate seepage from the landfill unit, as referenced under 35 IAC 811.317. The assessment includes the presentation of the following: 1) development of a conceptual model of the facility; 2) translation of the conceptual model into a mathematical model; 3) model simulations of surrogate compounds; 4) sensitivity analysis; and 5) analysis of model results.

2.1 CONCEPTUAL MODEL

Downgradient leachate constituent concentrations are controlled by advection, dispersion, and the mass flux through the landfill liner. Advection is the component of transport due to groundwater flow and is represented in the model by the average linear groundwater velocity. Hydraulic conductivity, hydraulic gradient, and effective porosity are used to determine the average linear groundwater velocity. Hydraulic dispersion is the dilution and spreading of the solute as a result of mechanical mixing and molecular diffusion. The mass flux of constituents through the asphalt liner is controlled by the: 1) constituent concentration in leachate; 2) the gradient across the liner; and 3) the area of infiltration through the liner. Each of these components affect contaminant transport from the landfill and will be briefly discussed below. Specific values used to determine the advection, dispersion, and mass flux components will be discussed individually in Section 2.5.

Advection

The site hydrogeologic setting must be presented in order to better understand the factors affecting advection. The WRL site is located on a topographic high between Kilbuck Creek to the west and unnamed intermittent streams to the north and south. The site-specific hydrogeologic investigation indicated that unconsolidated sand and gravel glacial drift sediments underlie the western portion (downgradient side) of the landfill, while fractured dolomite bedrock underlies the eastern (upgradient) portion of the landfill (Figure 2.1). The

predominant groundwater flow direction in the vicinity of the permitted waste area is west-northwest towards Kilbuck Creek. A careful review of the well logs, water level measurements, aquifer test data, and onsite slug tests from site wells (Figure 2.2) indicates that both the unconsolidated sand and gravel and the upper part of the dolomite bedrock are water bearing and hydraulically connected. Therefore, the uppermost aquifer includes both the unconsolidated sand and gravel and the upper part of the dolomite bedrock (GeoTrans, 1995a). However, it is important to note that the sand and gravel aquifer is the principal transport pathway from the landfill as shallow bedrock groundwater flows upward and discharges into the sand and gravel aquifer. This is shown based on observed upward groundwater gradients between unconsolidated and bedrock zones and the lack of leachate constituents in bedrock (GeoTrans, 1995b). Therefore, the GIA modeling addresses flow through the sand and gravel aquifer.

On the west side of the landfill, the depth of the alluvium ranges from 40 feet to greater than 70 feet above the dolomite bedrock. The thickness of the sand and gravel across the site increases from east to west, from the bedrock upland in the east toward the bedrock valley in the west. The water table intersects the alluvium/rock contact along a northeast-southwest line that can be drawn from boring B10A to boring B13, with the water table present within the bedrock east of this line. Therefore, the saturated thickness of sand and gravel increases from negligible at that line, to at least 55 feet at the west end of the landfill (see Figures 2.3 through 2.9). This increase in thickness from east to west is also apparent in the water table gradient. The gradient decreases from east to west, with increasing thickness of the more transmissive saturated sand and gravel.

In addition to aquifer thickness, the direction and magnitude of the observed hydraulic gradient determines the groundwater flow direction and resulting contaminant transport migration pathway. Based on groundwater and surface water elevations shown on potentiometric maps (Figures 2.10 through 2.21), the typical groundwater flow directions are generally from the bedrock upland recharge area east of the site to the alluvial deposits and discharge area (i.e., Kilbuck Creek) west of the site. Shallow groundwater discharges to Kilbuck Creek, which flows within 250 feet of the western boundary of the site. However,

based on monitoring data, groundwater flow in the alluvial aquifer also underflows Kilbuck Creek. Finally, hydraulic conductivity and porosity contribute to the advective term. Given that the water table aquifer consists of sand and gravel, a transmissive aquifer is expected in the conceptual model.

Dispersion

A sand and gravel glacial aquifer also consists of inherent variability in grain size distribution and variability in the distribution of coarse and fine-grained material vertically and areally. The unconsolidated deposits on site contain varying amounts of silt and clay within a matrix of sand and gravel. This variation in the amount of silt and clay occurs on a relatively small scale (i.e., much smaller than the size of the landfill), resulting in local variations in groundwater flow directions on a small scale. This variability or heterogeneous nature of the aquifer will result in the dilution of the solute as a result of mechanical mixing and molecular diffusion. However, because it is impossible to incorporate the site-specific heterogeneities that cause the mechanical dispersion and the thermal-kinetic energies that cause the diffusion, dispersion terms must be utilized to represent the spread of solute and simulate the effect of the heterogeneities.

Mass Flux

The mass flux of constituents through the asphalt liner incorporates the area of the leachate source, the leachate head acting on the liner, the liner permeability, and the concentration of leachate constituents. The conceptual model for contaminant transport utilizes a constant source area and concentration. The concentrations are based on site leachate sampling results, while the area is based on design considerations. Liner permeability is determined from site testing data of the asphalt liner that underlies the waste unit. The determination of the source is discussed in more detail in Section 2.5.1.

Figure 2.22 depicts the conceptual model and demonstrates the hydrogeologic setting in a simplified form, as it will be viewed by the model. This figure illustrates the sand and gravel aquifer as it increases in thickness to the west toward Kilbuck Creek. Dolomite

bedrock occurs in the eastern portion of the site where the contact exists approximately between B10A and B13. A source area and landfill invert are depicted in the southwestern portion of the landfill where LCM5 is present. As stated earlier, the landfill was designed with an asphalt liner overlain by a sand drainage layer that slopes at approximately one to two percent toward the landfill invert. The source area is the remaining zone of saturated leachate after the leachate head is reduced at the invert by the leachate collection system. Accumulated leachate will infiltrate the asphalt liner and the unsaturated aquifer materials below the landfill. Upon reaching the watertable, leachate constituents will be mixed and transported with groundwater flowing to the west.

2.2 TRANSLATION TO MATHEMATICAL MODEL

To translate the hydrogeologic and contaminant transport information into a mathematical model for simulation, several assumptions are necessary in order to reduce the governing equation to a form allowing an analytical solution. The following assumptions were utilized in the development of the mathematical model:

1. The aquifer is uniform in thickness.
2. A uniform gradient/flow field exists. It is assumed that uniform groundwater flow is parallel to the positive X-direction. The Y-direction is defined as horizontally transverse to the X-direction, and the Z-direction is defined as vertically transverse to the X-direction.
3. The aquifer is a homogeneous and isotropic transport medium; therefore, all aquifer parameters (e.g., hydraulic conductivity, porosity, thickness, bulk density) are constant.
4. Transport occurs only in two dimensions (length and width).
5. Values for dispersivity, assumed to be constant throughout the aquifer, may vary with direction (i.e., longitudinal, horizontal transverse and vertical directions).
6. Constituent concentrations in the leachate are constant.

Each of these assumptions will be discussed in Section 2.5 as they pertain to the model input values.

Figure 2.23 represents the simplifications to the conceptual model such that it can be simulated with a mathematical model. Notice that the conceptual model represents the sand and gravel aquifer as an aquifer with a uniform thickness of 35 feet. The source is shown to be fully penetrating (35 feet) and oriented perpendicular to the direction of groundwater flow. Figure 2.23 depicts a centerline of transport, which is used for concentration profiles. Concentrations of leachate constituents are highest along the centerline.

2.3 MODEL SELECTION

The mathematical computer model AT123D was chosen for the GIA. AT123D, or Analytical Transient One-, Two-, and Three-Dimensional Simulation of Waste Transport in the Aquifer System (Yeh, 1981) is a three-dimensional, semi-analytical transport model that predicts chemical distribution with time from a mass release into the aquifer. The model incorporates: 1) physical, chemical, and biodegradation of contaminants; 2) hydraulic properties of the saturated porous media; and 3) dispersivity in three perpendicular directions within a specified uniform advective flow field.

AT123D mathematically incorporates various input parameters which account for retardation, longitudinal dispersion, horizontal transverse dispersion, and vertical dispersion. These processes are modeled throughout a uniform aquifer of finite or infinite width and depth. Input parameters are discussed in Section 2.5.

AT123D was selected because it is a simple and reliable model that is appropriate for the WRL site conditions. Its reliability has been evaluated by numerous investigators, as described below. This model is particularly well suited to applications typically encountered in a landfill setting. The equation utilized within the model to govern the distribution of contaminants within the aquifer is presented below.

The equation is described in seven terms or segments (A through G as shown below) with respect to the site-specific modeling efforts. The equation is presented in Yeh (1981),

with a brief description of each term within the equation, as well as definitions of each variable within the equation.

$$\left[\frac{\partial n_e C}{\partial t} \right] = \frac{\nabla \cdot (n_e D \nabla C)}{B} - \frac{\nabla \cdot C q}{C} + \frac{M}{D} - \frac{K n_e C}{E} - \frac{\lambda n_e C}{F} - \left[\frac{\partial (\rho_b C_s)}{\partial t} + \lambda \rho_b C_s \right] / G$$

where:

- q = Darcy velocity vector (LT⁻¹)
- D = Hydraulic dispersion coefficient (L²T⁻¹)
- C = Dissolved concentration of the solute (ML⁻³)
- C_s = Absorbed concentration in the solid (MM⁻¹)
- ρ_b = Bulk density of the media (ML⁻³)
- M = Rate of release of the source (MT⁻¹)
- n_e = Effective porosity of the aquifer
- λ = Radioactive decay constant (T⁻¹)
- K = Degradation rate (T⁻¹)
- t = Time (T)
- ∇ = Gradient

Term A of the above equation refers to the rate of change of the dissolved contaminant mass per unit volume of the aquifer.

Term B refers to the combined effects of hydraulic dispersion and molecular diffusion. Hydraulic (or mechanical) dispersion will dominate molecular diffusion due to the relatively high linear groundwater velocity through the sand and gravel aquifer, as compared to the rate of molecular diffusion.

Term C refers to the effects of advective transport, taking into account the Darcy groundwater velocity and the dissolved concentration of the solute. Advective transport is

the process by which contaminants or solutes are transported by the bulk movement of the groundwater.

Term D refers to the mass release rate for each individual constituent modeled. The mass release rate (mass flux) is dependent upon the initial leachate concentration of the constituent, the maximum leachate head present above the liner, liner permeability, and the size of the source area.

Term E refers to the effects of chemical and biological degradation. Term F refers to the effect of radioactive decay, which does not apply in the modeling conducted for the GIA because radioactive waste is not the subject of the modeling effort.

Term G refers to the effects of ion exchange or sorption (adsorption coefficient or K_d) of the individual constituents. Adsorption coefficients are specific to individual constituents, and can be related to the organic content of the porous media.

2.4 MODEL RELIABILITY

The computational reliability of the model has been evaluated through many comparisons to analytical models. The supplementary instructional manual (Trussell and Hoopes, 1987) contains comparisons of the AT123D solution to hand calculations using AT123D's governing equation. Huyakorn et al. (1987) also noted that results obtained with AT123D were highly consistent with a similar analytical transport model which treats the source concentration as a Gaussian distribution in the lateral direction. The appropriate application of using Green's functions for solving the advection-dispersion equation (the basis for AT123D) is discussed by Ellsworth and Butters (1993) and Gayla (1987). In addition, the International Ground Water Modeling Center (IGWMC), in Golden, Colorado, has checked AT123D results against results of other analytical models including SOLUTE, PLUME2D and PLUME (all available through IGWMC). Variations in results were generally small (between one and ten percent), occurring primarily near the edges of the plume. The references cited are included in Appendix E. Therefore, given the assumptions stated in the manual and discussed below, AT123D provides a reliable calculation of contaminant transport.

2.5 MODEL INPUT VALUES

The following section provides a discussion of model input parameters necessary for simulation with AT123D. Table 2.1 summarizes the selected model input parameters for the model simulations.

Groundwater transport of constituents from the landfill is controlled by advection, dispersion, and mass flux through the liner. Site-specific model parameter values for these components were assigned whenever possible. Reasonably conservative values were assigned whenever site-specific data were not available (e.g., dispersivity). In addition to advection, dispersion, and mass flux input values, the following input parameters are also described herein: aquifer dimensions, source thickness, retardation/decay, density of water, time discretization.

2.5.1 CONTAMINANT SOURCE MASS FLUX

The mass flux of a contaminant is determined from the product of the volumetric flux of water and the contaminant concentration. Specifically, the liner conductivity, gradient, area, and concentration are utilized. This constant value is input into the model as a contaminant mass per unit time. This mass flux is essentially the product of the liner leakage rate, source area, and leachate concentration:

$$M = Q * A * C = K * (dh/dl) * A * C$$

where:

M	=	Mass flux
Q	=	Flow through the liner
A	=	Source area
C	=	Leachate concentration
K	=	Liner hydraulic conductivity
dh	=	Head loss across the liner
dl	=	Liner thickness

Each of these parameters as they are incorporated into the formulation of the mass flux are discussed herein.

Source Area

The area of the leachate source is based on several assumptions. First, after the landfill is capped with a geomembrane composite cover, infiltration (0.02 in/yr) and thus leachate generation is minimal. Second, leachate collection has been performed to lower the leachate head to two feet at the landfill invert (LCM5), which reduces the area of saturated leachate (source area). Third, although the source area will be circular in shape, it is represented in the model as a square oriented perpendicular to the predominant groundwater flow direction (Figure 2.23). These assumptions are discussed below.

The WRL was designed and constructed with an asphalt liner and a leachate collection system. As stated previously, the GIA modeling accounts for the reduction of leachate head levels above the landfill liner. WRL is currently preparing a leachate management plan to reduce the leachate head levels in the landfill, which will be implemented in the near future. This plan will feature a combination of operational modifications, in the form of leachate removal, as well as design modification in the form of a low permeability geomembrane composite cover. The cover will include a 30 mil, very low density polyethylene (VLDPE) membrane which will exceed the requirements of 35 IAC 811. Placement of the upgraded cover will be initiated when 25 percent of the landfill attains final grade, and will be constructed in phases throughout the operational life of the landfill. The cover will be completed within 60 days of the landfill reaching final grade. The combination of leachate collection and the low permeability cover will reduce the leachate level within the landfill to a maximum of two feet. Infiltration through the proposed cover has been simulated using the HELP model. The infiltration is estimated to be 0.02 inches per year (Appendix A).

At the completion of leachate removal, approximately two feet of leachate will exist above the liner. It is predicted that this two feet of leachate will exist in the western portion of the landfill in the vicinity of an existing leachate collection manhole. This leachate

collection manhole or sump (LCM5, Figures 2.22 and 2.23), exists at the lowest elevation of the liner. The collection sump was constructed as an invert with sloping sides conservatively assumed to be one to two percent. Furthermore, the entire liner slopes toward this invert. Therefore, after removal of the leachate, which has accumulated throughout the operational period of the landfill, remaining leachate will be confined to this invert.

Because the leachate acting on the liner collects in a sloped invert, the area in which leachate occurs is dictated by the liner slope and the maximum head in the invert. Given that the maximum head that will occur during the 100-year simulation period is two feet and that the slope of the invert is one to two percent, a conservative assumption of source area can be determined. Assuming that the sump location is shaped like an inverted pyramid, and that the slope is approximately 1.5 percent, the source area is determined to be 267 x 267 feet (Appendix B).

Gradient

The liner thickness and leachate head are used to calculate the gradient across the liner. A liner thickness of two inches was used in the model, and is based on the design and installation reports of the asphalt liner (Chicago Testing Laboratory, 1969). Because of the sloped nature of the invert, the maximum head acting on the liner is two feet. The average head is one-half of this value, or one foot (see Appendix B). Therefore, the gradient across the liner is calculated to be 6.88 ft/ft (see Appendix B). Based on mass balance calculations (Appendix B), the amount of leachate head acting on the liner will actually decrease below two feet after the cover is installed and leachate removal is terminated. In other words, the leachate head is expected to continue to decrease below two feet because the infiltration through the composite cap is less than the leakage through the liner. Plots of leachate head versus time based on HELP Model calculations are presented in Appendix B. In conclusion, the assumption of both a constant area and leachate level in the model for the entire 100 years is conservative because leakage rates will actually continue to decrease over time.

Landfill Liner Conductivity

Permeability testing was performed on several proposed design mixes for the asphalt liner, as well as the final design. A hydraulic conductivity value of 2.7×10^{-8} cm/sec was included in the model based on the testing results. This value is the geometric mean of four tests results (Appendix B).

Leachate Constituent Concentrations

Concentrations of leachate constituents have been determined from the following sources: (1) five rounds of individual analysis of leachate at wells sampled during the Remedial Investigation (RI) in 1988; (2) an individual sample collected on October 4, 1990; (3) a composite of 45 wells on November 26, 1990; (4) four groups of five-well composites from April 27, 1992; and (5) individual analysis of leachate at four locations on March 30, 1995 (Appendix C). The type of data collected presents a small difficulty in obtaining a straight-forward representation of individual leachate constituents. Specifically, the analyses are from either composites or individual wells. If one were to average these results, individual well analysis results would have the same "weight" as the composite samples. In addition, the data have been collected over the course of seven years and concentrations of constituents in the leachate are expected to decrease over time through degradation and mass reduction (historical data from the site and literature demonstrate this). Furthermore, composite analyses are not recommended for use in model input (IEPA, 1995). Therefore, the more recent data (1995) were used in developing representative constituent concentrations.

Table 2.2 illustrates the 1995 values with the resultant concentrations of constituents in leachate used in the model. The mean concentration plus two standard deviations provided a conservative estimate of each leachate constituent concentration. Specific conductance values are derived similarly from the four groups of five-well composites (April 27, 1992). Notice that the mean leachate concentration of specific conductance plus two standard deviations is less than the AGQS of 2350.22 umhos.

These concentrations of leachate constituents are actually expected to decline throughout the life of a landfill, therefore, conservatism is added to the model by keeping the input concentrations constant throughout the 100-year simulation period after clean-up. Furthermore, given that there will be some period of time between the present and the completion of the groundwater remediation, concentrations at that time will be less than reported in 1995.

2.5.2 ADVECTION PARAMETERS

Because the model assumes a homogeneous and isotropic aquifer, representative hydraulic gradient, porosity, and hydraulic conductivity values must also be implemented.

Hydraulic Gradient

Since the hydraulic gradient varies across the site, the hydraulic gradient was calculated from the vicinity of the source area to the ZOA along the principal direction of groundwater flow. Based on the historical water levels, a value of 0.005 ft/ft was estimated. Figures 2.10 through 2.21 depict inferred groundwater elevation contours for seasonal conditions. Table B-1 and Figures B.1 through B.12 in Appendix B demonstrate the historical groundwater gradients observed in the source area used to estimate the hydraulic gradient.

Hydraulic Conductivity

Hydraulic conductivity data have been collected at the WRL site using numerous slug tests and a one eight-hour pump test (Appendix B). It is commonly accepted that conductivity estimates derived from pump tests are significantly more reliable and representative than slug tests, especially for higher permeability sediments. Therefore, the value for hydraulic conductivity used in the model is based on results from the eight-hour pump test. This value has been determined to be 1500 ft/day, which is the geometric mean of each of the values determined at each well (Appendix B). The modeled value is consistent with values of hydraulic conductivity reported in literature for sand and gravel materials (Boulding, 1995).

Porosity

The porosity value was determined based on the mean of 12 laboratory-determined porosity values (Appendix B). The porosity values ranged from 24.9 percent to 35.4 percent and the arithmetic mean was determined to be 30.4 percent. This modeled value is consistent with values of porosity reported in literature for sand and gravel materials (Boulding, 1995).

2.5.3 DISPERSION PARAMETERS

Values for longitudinal and transverse dispersivity are conservatively based on the expected travel distance from the source. The longitudinal dispersivity is estimated to be 10 percent of the travel distance. Based on Figure 2.23, the travel distance from the middle of the source area (LCM5) toward the northwest along the predominant direction of groundwater flow to the point of compliance boundary is 1,080 feet. The longitudinal dispersivity value is calculated to be 108 feet. The value for transverse dispersivity is estimated to be 20 percent of the longitudinal dispersivity (108 feet \times 0.20 = 21.6 feet) per IEPA Guidance "Instructions for the Groundwater Protection Evaluation for Putrescible and Chemical Waste Landfills," Appendix C to LPC- PA2 (rev. 10/21/92).

2.5.4 ADDITIONAL MODEL INPUT PARAMETERS

In addition to the components outlined above, the AT123D model requires input values for aquifer dimensions (thickness and aquifer width), source thickness, density of water, retardation/decay, molecular diffusion, and time discretization.

Aquifer Dimensions

Aquifer width and depth are required model input parameters, and are based on observed conditions at the site. Based on previous hydrogeological investigations at WRL, it is apparent that actual aquifer width is much greater than the areal extent of the contaminant plume (GeoTrans, 1995a). Therefore, the aquifer width is defined as infinite for the purpose of the contaminant transport modeling.

Aquifer depth (i.e., saturated thickness) was determined from boring logs generated during hydrogeologic investigations. The modeled saturated thickness of the unconsolidated sand and gravel was chosen based on the average thickness of 35 feet across the zone of transport (source to ZOA). Geologic logs from P5 and G104 indicate an average saturated thickness of 35 feet. The average saturated thickness at G104 and P5 is 45 feet and 25 feet, respectively. Therefore, the saturated thickness in the model is calculated to be 35 feet. This value is supported by the presence of impacted groundwater in the lower part of the aquifer at MW106. MW106 is screened at depth, immediately downgradient of the waste boundary, and contains elevated levels of leachate constituents.

Source Thickness

The solute transport model conservatively simulates only two-dimensional transport. In other words, the model disregards any lowering in concentrations due to vertical dispersion. In order to balance this added conservatism, a fully penetrating source is utilized. Therefore, the source thickness is equivalent to the aquifer thickness of 35 feet.

Density of Water

The density of water included in the modeling is 1000 kg/m³.

Retardation/Decay

AT123D permits the incorporation of retardation and first-order decay. However, the conservative assumption that biodegradation and retardation of contaminants will not take place was utilized for each of the constituents modeled with the exception of ammonia. Therefore, for constituents other than ammonia, the adsorption and decay coefficients were equal to zero (0). Likewise, the soil bulk density is not utilized for parameters other than ammonia. For completeness, the data sets included in Appendix D include an input value of 1855 Kg/m³. The calculation of the soil bulk density, which is used in the ammonia simulations, is included in Appendix B. It is anticipated, however, that biodegradation of

many leachate constituents occurs within the zone of attenuation and that this process will serve to further reduce resultant constituent concentrations within the groundwater.

Molecular Diffusion

Molecular diffusion was assumed to be zero (i.e., a conservative estimate). Given the high hydraulic conductivity and the relatively high linear groundwater velocity of the alluvial aquifer, the effects of molecular diffusion are assumed negligible relative to advection and mechanical dispersion.

Time Discretization

The final input value for the AT123D model involves time stepping or time discretization. The transport simulations utilize 7300 time steps of 120 hours each to reach 100 years.

3 MODELING RESULTS

Figure 2.23 illustrates the centerline of contaminant transport from the source area to the downgradient edge of the zone of attenuation. The highest concentrations of leachate constituents will occur along this line. From a technical standpoint, this centerline has the highest concentrations of the plume because it is the direct flow path unaffected by lateral dispersion. Therefore, to assess the impact to groundwater at the edge of the zone of attenuation, concentrations of leachate constituents were evaluated at the intersection of the centerline and the downgradient edge of the ZOA.

The results presented in this section are presented as both normalized concentrations and constituent-specific concentrations. Normalized concentrations are modeled by including a unit concentration in the calculation of the mass flux term (Section 2.5). This unit value is 1.0 mg/L. Because leachate constituents are reported in mg/L in Section 2.5, the concentration for each constituent can be determined using its individual leachate constituent source concentration. Concentrations predicted by the model are considered to be additive, i.e., while the input leachate is 1.0 mg/L, the resident groundwater is 0 mg/L.

3.1 SURROGATE MODELING APPROACH

Surrogate modeling is utilized in the GIA to represent groups of leachate constituents rather than modeling and presenting each leachate constituent individually. As stated in Section 2, with the exception of ammonia, the constituents detected in leachate are modeled without the attenuation effects of retardation and decay. Therefore, the non-ammonia constituents have equivalent transport parameters. The non-ammonia constituents each have a distribution coefficient (K_d) of 0 (no retardation) and a decay constant of 0 hr⁻¹ (no decay). The remaining differences among the constituents are their concentration in leachate and their AGQS values. Leachate constituents are grouped by similar leachate concentrations and AGQS. Table 3.1 lists the surrogate groups. There are two individual compounds modeled

and five surrogate groups. Ammonia is modeled separately due to the fact that biodegradation and retardation are included as input parameters in the transport simulation. Mercury is presented separately because of its low AGQS. Chloride and alkalinity are modeled together as one surrogate due to their high leachate concentrations. The remaining inorganics have been combined into four surrogate groups, while the organics are represented in one surrogate group. It should be noted that the highest leachate concentration within a group was modeled and compared to the lowest AGQS within that group. This produces an additional level of conservativeness in the model results.

Demonstration of compliance requires the presentation of leachate concentrations versus time at five year intervals during the 100 year simulation period. For the WRL model, however, steady-state conditions were achieved prior to five years. Figure 3.1 depicts the normalized concentrations versus distance through time for the baseline model run (Run 80). It is evident from both the model output and the graph that steady-state conditions are reached by 155 days for the baseline normalized model run. Constituent concentrations do not change once steady-state conditions are established. Because the concentrations for all leachate constituents (except sensitivity runs for ammonia) are based on the normalized concentration run (Run 80), their concentrations also will not change after 155 days. It should be noted that steady-state concentrations are the maximum possible concentrations at a given point for any time. Therefore, an evaluation using steady-state conditions is conservative.

3.2 SURROGATE MODELING RESULTS

A single model simulation (Run 80) was performed to create baseline normalized results. As stated previously, the concentrations of leachate constituents at the zone of attenuation can be obtained by the product of the normalized concentration and the leachate concentration. Thus, the steady-state concentration of any constituent can be obtained from the baseline plot (Figure 3.1). For example, the normalized concentration at the downgradient edge of the ZOA for the baseline model is 0.000242 and the leachate

concentration for chloride is 4940.5 mg/L. Therefore, the resulting chloride concentration at the edge of the ZOA along the centerline is 1.2 mg/L.

Figures 3.2 through 3.9 show steady-state (maximum) concentrations versus distance from the waste boundary along each surrogate plume centerline. As expected, the concentrations of each surrogate group decrease at greater distances from the waste boundary. Based on these model results, Table 3.2 presents the concentrations of the surrogate group constituents at the downgradient edge of the ZOA in comparison with their AGQS. The product of the leachate concentration and the normalized concentration at the ZOA yields the surrogate concentration at the point of compliance. It is apparent that the concentration of each surrogate group is below its AGQS. This, also, inherently implies that all of the leachate constituents listed in Table 3.1 are also below their respective AGQS at the edge of the ZOA within the 100 year simulation period. Figures 3.10 through 3.17 demonstrate the surrogate concentrations within the ZOA through time.

3.3 SENSITIVITY ANALYSIS

Sensitivity was conducted for the following key model parameters: 1) hydraulic conductivity; 2) hydraulic gradient; 3) porosity; 4) uniform aquifer thickness; 5) dispersivity; 6) time interval for model solutions; 7) liner conductivity; 8) invert slope (source area); 9) leachate head (source area); and 10) source concentration. Table 3.3 presents the values changed to assess model sensitivity to each input parameter. Results are summarized in Table 3.4 and Figures 3.18 through 3.27.

Hydraulic Conductivity (K)

Sensitivity was conducted on hydraulic conductivity by utilizing 100 ft/day and 3,000 ft/day (Runs 81 and 82). This range is consistent with values for sand and gravel reported in Boulding (1994) for eight different literature sources. The very low conductivity values determined during slug testing are inconsistent with both the aquifer test data and literature values. These low values are most likely caused by the build-up of fine materials near the well screen. The low conductivity value used in the sensitivity run is instead based on the

reported value at MW106, which is approximately 100 ft/day (GeoTrans 1995a), and is consistent with the observed range for sand and gravel deposits (Boulding, 1995). The high hydraulic conductivity sensitivity run was based on a value two times greater than the base case conductivity. Sensitivity results indicated that when using a conductivity of 3,000 ft/day, the concentrations at the ZOA are lower than those results obtained from using a value of 1500 ft/day. This is due to the rapid contaminant transport through the aquifer which results from a high hydraulic conductivity. This rapid rate of contaminant transport results in increased dilution, in turn causing a decrease in constituent concentrations at the zone of attenuation. Conversely, when using a low hydraulic conductivity of 100 ft/day, the contaminant concentrations at the ZOA are significantly higher than those results obtained from using a conductivity value of 1500 ft/day. This low hydraulic conductivity (100 ft/day) is not representative of the site sand and gravels, however. The value for hydraulic conductivity used in the base case (1500 ft/day), which was determined through an eight-hour pump test and confirmed with flow model calibration, is significantly more reliable than the short-term slug test data. Calculation of the mean value of hydraulic conductivity is included in Appendix B. Results are summarized in Table 3.4, and are presented graphically in Figure 3.9. Both Figure 3.19 and Table 3.4 demonstrate compliance even with the incorporation of the lower hydraulic conductivity value.

Hydraulic Gradient (I)

A sensitivity analysis was conducted on hydraulic gradient by simulating the lowest and highest observed gradients at the site (Runs 83 and 84). Calculations are presented in Appendix B. Results indicated that when using a shallow gradient of 0.003, the contaminant concentrations were higher in the ZOA than the base case (0.005). The lower gradient results in a lower flow velocity which one might assume reduces contaminant concentrations downgradient. However, in combination with less advection and less spreading of the leachate constituent plume, concentrations are in fact greater. Use of the higher gradient (0.009) results in lower concentrations in the ZOA than that of the base case. This is due to the more rapid flow through the aquifer as a result of a steeper gradient and greater spreading

of the contaminant mass. Results are summarized in Table 3.4, and are presented graphically in Figure 3.19. Both Figure 3.19 and Table 3.4 demonstrate that compliance is maintained when incorporating the more restrictive gradient (0.003) which results in higher concentrations.

Porosity (n)

Sensitivity was conducted on porosity using values both 33 percent greater (0.40) and 33 percent less (0.20) than the value of 0.30 (model calibration value). The range of porosity encompassed by the sensitivity runs is consistent with porosity values of sand and gravel aquifers reported in literature (Boulding, 1994). As presented in Table 3.4 and evident by the concentration vs. distance graph (Figure 3.20), the model is not sensitive to porosity. In comparison to the base case (Run 80), equivalent concentrations occur in the ZOA.

Source Release

Sensitivity of the model to the waste release rate (i.e., mass flux) can be assessed by changing various parameters: 1) leachate concentrations; 2) leachate head acting on the liner; 3) source area; and 4) asphalt liner hydraulic conductivity. However, because each of these site-specific parameter values were used to determine the mass flux, each was addressed separately.

Source Concentration

Leachate constituent concentrations were increased and decreased 20 percent. This was achieved by varying the normalized concentration from 1.0 mg/L to 1.2 mg/L and 0.80 mg/L. It is evident that increasing the leachate concentrations will result in higher concentrations in the ZOA. Therefore, it is important not to underestimate the source concentration. The base case model input parameter for leachate constituent concentrations is inherently conservative for three reasons: First, one-half of the detection limit was used in the calculation of the mean when a parameter was not detected by the laboratory analysis; secondly, two standard deviations are added to the mean to determine the model

concentration; and third, based on historical concentrations in leachate and literature from other existing landfills, leachate constituent concentrations at WRL are expected to decrease through time through the physio-chemical process of leaching. Furthermore, leachate concentrations in the future are expected to decrease below the 1995 values upon completion of groundwater remediation, the point at which the model simulation begins (Section 1). Therefore, the existing leachate concentrations are a reasonable representation of the WRL conditions at the time of modeling.

Results are summarized in Table 3.4 and are presented graphically in Figure 3.21. It is clear from the graph and the summary table that compliance of the ZOA is maintained even with an increased concentration.

Liner Conductivity

The liner conductivity was assessed by using the high and low values of laboratory-determined conductivity. As reported in Appendix B, several conductivity values were determined for the asphalt liner. The sensitivity analysis includes the lowest determined value, 4.7×10^{-9} cm/sec (Run 94) and the highest, 1.82×10^{-7} cm/sec (Run 93). Figure 3.22 illustrates the variation in the concentration with distance as a result of this change. Table 3.4 demonstrates that even with these changes, concentrations of leachate constituents at the edge of the ZOA are below their respective AGQS.

Leachate Head

Because of the sloped invert, an increase or decrease in leachate head will result in changes in the gradient across the liner and the size of the source area. When the leachate head is raised to four feet (Run 98), the source area increases to 533 feet x 533 feet and the gradient increases from 6.9 to 12.8. A decrease in leachate head will have the opposite effect. With a leachate head level of one foot, the area is 133 feet x 133 feet and the gradient across the liner is 3.94 (Appendix B). A change in the leachate head level will affect the source release rate (Section 2.5) such that the higher leachate head results in a mass flux of 0.000328 kg/hr. Whereas, the reduced head results in a mass flux of 6.3×10^{-6} kg/hr. Figure

3.23 illustrates that the model is sensitive to the mass flux, as could be expected. However, Table 3.4 demonstrates that the AGQS for the surrogate groups is not surpassed at the edge of the ZOA within 100 years.

Invert Slope

Because the invert is sloped, the area of the source is controlled by the leachate head level and the value of slope. While maintaining two feet of leachate, as in the base case (Run 80), a decrease and increase in the slope will increase and decrease the source size, respectively. Appendix B shows the variation in the source size with one percent slope (Run 95) and two percent slope (Run 96). As expected, the mass flux changes with these variations. The base case slope value is currently 1.5 percent, which is to be considered conservative, as the slope of the liner across the landfill is approximately one to two percent. It is more likely that the slope in landfill invert, which is designed as a sump, is higher than one to two percent. Figure 3.24 and Table 3.4 demonstrate that as a result of the changes in slope, the model still demonstrates compliance within 100 years at the ZOA.

Aquifer Saturated Thickness

Sensitivity analysis was conducted on the saturated thickness and thus the waste penetration thickness. The reduction of thickness to 25 feet (Run 88) slightly increases the concentrations at the ZOA. Conversely, as expected, the increase in thickness (Run 87) results in decreased concentrations in the ZOA. A thickness of 25 feet represents the minimum saturated thickness of the sand and gravel. As stated previously, the aquifer thickness increases to 70 feet at the west end of the landfill. As with the other sensitivity runs, compliance at the downgradient edge of the ZOA is maintained, Figure 3.25 and Table 3.4.

Dispersivity

Sensitivity was conducted on longitudinal and horizontal dispersivity. Dispersivity values were obtained by utilizing both less and more conservative estimates of dispersivity

than the base case. While the base case run conservatively estimates the longitudinal dispersivity to be ten percent of the expected travel distance from the middle of the source, the two sensitivity runs (Runs 89 and 90) use values equal to five percent and 20 percent of the expected travel distance, respectively. The lateral dispersivity value is based on a percentage of the longitudinal dispersivity rather than expected travel distance. During the base case simulation the lateral dispersion was initialized as 20 percent of the longitudinal dispersion. For the assessment of sensitivity of the model to lateral dispersion, the low lateral dispersion run (Run 89) utilized a D_t ten percent of the D_l , while the higher dispersion run (Run 90) implemented a D_t of 20 percent of the D_l . The Sensitivity results for longitudinal and vertical dispersivity indicated that, as expected, as the dispersivity is decreased the resultant concentrations increase. Conversely, when the dispersivity was increased, the resultant groundwater concentrations decrease. Variations that result in increased concentrations in Run 90 were not significant and groundwater at the ZOA was not impacted within the 100-year post-remediation period, Figure 3.26 and Table 3.4.

Time Interval (DT)

Sensitivity analysis was conducted to determine the effects of varying the time interval (time step) for model solutions. In the base case simulation (Run 80), a time step of 120 hours (7300 total time steps of 120 hours equals 100 years) was utilized in conducting the base case model runs. Sensitivity was conducted by increasing and decreasing the time step to 219 hours and 24 hours, respectively (Runs 91 and 92). The results indicate that there is no sensitivity to time stepping when using AT123D to assess concentrations at increased distances away from the source. However, at close distances to the source, lower time steps are required. For the WRL modeling, concentrations are desired at relatively large distances from the source (at the ZOA 1000 feet downgradient of the source), therefore, changes in time stepping do not affect the resultant concentrations. This is evidenced in Figure 3.27.

3.4 AMMONIA SIMULATION

The model predicted concentrations for all the detectable leachate constituents was below the AGQSs for the baseline model simulations. However, the high leachate concentration and low AGQS for ammonia produced an exceedance during the worst case sensitivity analysis ($K = 100$ ft/day, Table 3.4). Since ammonia nitrogen exists as a cation at a pH near neutrality, it is readily immobilized through cation exchange (Ceazan et al., 1989 and Drever, 1988). In addition, nitrogen is often a limiting nutrient and is readily assimilated by soil bacteria (Andreoli et al., 1979). To more accurately model the fate of ammonia under natural conditions, retardation and biodegradation were incorporated into the model sensitivity simulations for ammonia.

Site-specific values for these terms are not readily available for most sites, including WRL. Therefore, values reported in literature were used to provide model input value estimates. Andreoli and others investigated the decreasing observed concentrations of ammonia with time and distance based on field data collected near a subsurface septic tank. Subsurface conditions (unconfined sand and gravel aquifer) were similar to the WRL site. Based on their findings, half-lives in groundwater ranged from 23 days to 72 days (Andreoli et al., 1979). Calculations are presented in Appendix B. Ceazan and others performed laboratory batch adsorption tests and tracer tests to determine K_d values in order to determine the retardation factor. The reported retardation factor values ranged from 2.0 to 3.5 (Ceazan et al., 1989). Drever (1988) reports a range of retardation factors for ammonia of 16 to 80 for sandstone aquifers. Based on these literature values, a retardation factor of 5 was estimated for use in the WRL analysis (Run 99A).

Figure 3.28 depicts the concentration of ammonia at four points in the ZOA through time where a retardation of five and a half-life of 62 days are used. As with previous results, it is evident that steady-state concentrations are reached prior to the 100-year simulation period. Figure 3.29 depicts the concentrations of ammonia versus distance from the waste boundary. It is apparent that concentrations of ammonia are less than the AGQS within the ZOA for the 100-year post-remediation period.

A sensitivity analysis was performed on the ammonia attenuation input values to examine the effect of parameter uncertainty. This simulation (Run 99B) included a low retardation factor of 2.0 and a high half-life of 72 days. Figure 3.30 shows the variation in ammonia concentration for this modeling scenario. It is evident from Figure 3.30 that ammonia does not exceed the AGQS, even when the low retardation and higher half-life are used. If the combined effects of the low K, low retardation, and a high half-life are simulated (Run 100), a seemingly worst-case scenario results. However, the lower K value (100 ft/day) accentuates the effect of the decay and retardation and lowers the ammonia concentrations even further than Run 99B. Run 100 is included in Appendix D.

3.5 SENSITIVITY ANALYSIS CONCLUSIONS

Sensitivity results indicate that by utilizing current leachate concentrations under future conditions of decreased leachate head, concentrations for the leachate constituents are below the respective AGQS at the boundary of the zone of attenuation within the modeling period of 100 years, even when the entire observed range of each model parameter is simulated. All model input parameters were varied to reflect to observed range of data onsite or the range of representative values. The model parameter value which causes the most significant change in concentrations is the lower conductivity value. However, as stated in Section 2, the aquifer pump test determined value of conductivity (1500 ft/day) is more representative of the actual aquifer value. Therefore, model results using the lower conductivity yield worse-than-expected concentrations. Even while simulating these worse-than-expected concentrations, AGQS values were not exceeded at the point of compliance at the edge of the ZOA.

3.6 MAPC DETERMINATION

The zone of attenuation is presented in Figures 2.22 and 2.23, as well as Plate 1. Within this ZOA, a network of verification and detection monitoring wells is proposed (GeoTrans 1995b). These wells serve as compliance wells at the ZOA for which Maximum

Allowable Predicted Concentrations (MAPCs) must be established. The MAPCs are concentrations that would indicate exceedance of an AGQS at the ZOA. This determination was performed by modifying the base case analysis model (Run 80) such that the concentrations of leachate constituents just exceed the AGQS at the downgradient edge of the ZOA along the centerline of contaminant flow (Run MAPC-1). The parameter which was increased, causing this hypothetical exceedance, was the mass release rate. Because there are many leachate constituents with varying leachate concentrations and AGQS, the constituent which would be exceeded at the earliest time frame was used. Specifically, the inorganic compound boron was used to signal exceedance at the ZOA. Table 3.5 presents the MAPCs for each leachate constituent based on model run MAPC-1.

3.7 LIMITATIONS AND UNCERTAINTIES

Model predictions are limited in that the results are based on the current observed field conditions and model parameters. Spatial heterogeneity exists at the site, as demonstrated in Section 2 and GeoTrans 1995a. This heterogeneity is not included in the model due to AT123D limitations, as well as the practical limitation of fully characterizing the heterogeneous nature of the site. The sensitivity analysis was included to assess the effects of these uncertainties. The combination of conservative assumptions and the sensitivity analysis will tend to over-predict concentrations, and, thus, provide a sound, defensible scientific and engineering basis of concluding that the facility will not impact groundwater quality within the ZOA.

4 SUMMARY AND CONCLUSIONS

The GIA presented in this submittal was performed in accordance with 35 IAC Section 811 and guidance documents provided by the IEPA. A groundwater transport model using AT123D was developed for the site to assess the potential impacts to groundwater after groundwater remediation is complete and source reduction measures have been completed.

The groundwater transport model described in this report was based, to the fullest extent possible, on site-specific data and engineering design. Major model input parameters such as hydraulic conductivity, thickness, hydraulic gradient, and leachate concentrations were based on site-specific data. Where field data were lacking, and parameter values were estimated based on conservative literature values (e.g., dispersivity), sensitivity analysis showed that the model was relatively insensitive with respect to the AGQS to changes to these parameters. Consequently, the conceptual model, which was developed and translated into a mathematical model, is reliable for assessing potential impacts to the groundwater from the landfill unit.

The model incorporated several simplifications and conservative assumptions that will tend to over-predict the potential impact of the existing unit. These assumptions include: 1) constant source release rate (constant leachate head, area, and concentrations); 2) increased source area as a result of using a low invert slope; 3) no retardation or biodegradation of contaminants (excluding ammonia); 4) no dilution as a result of precipitation recharge; and 5) no attenuation through vertical dispersion. Even with the conservative assumptions, the GIA demonstrates that there will be no predicted exceedance at the zone of attenuation of groundwater standards established in accordance with 35 IAC Section 811.320.

Based on the demonstrated compliance of the GIA with IEPA-recommended procedures, and the acceptability of the predicted concentrations, the GIA should be determined to be favorable.

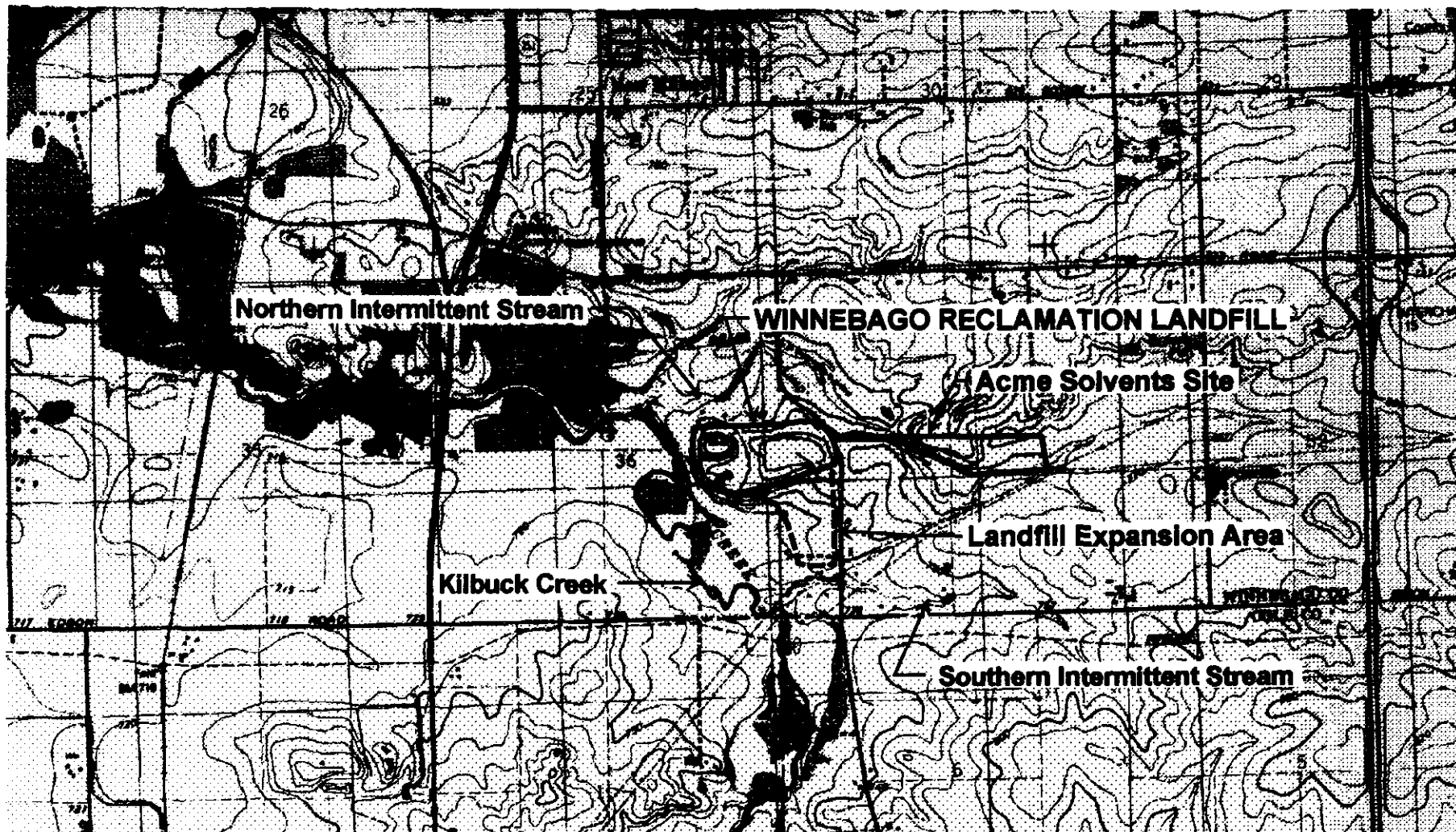
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NOTE:
 BASE MAP DEVELOPED FROM ROCKFORD SOUTH, ILLINOIS
 7.5 MINUTE USGS TOPOGRAPHIC QUADRANGLE MAP
 FIELD CHECKED IN 1992. MAP EDITED IN 1993.

SITE LOCATION



TITLE:

SITE LOCATION MAP

LOCATION:

Winnebago Reclamation Services, Rockford, IL.

GeoTrans, Inc.
 GROUNDWATER SPECIALISTS

CHECKED:	D.S.
DRAFTED:	P.K.
FILE:	7736001A.D84
DATE:	6-10-95

FIGURE:

1.1

WEST

EAST

ACME Solvent Site

Winnebago Reclamation Landfill

Kilbuck Creek

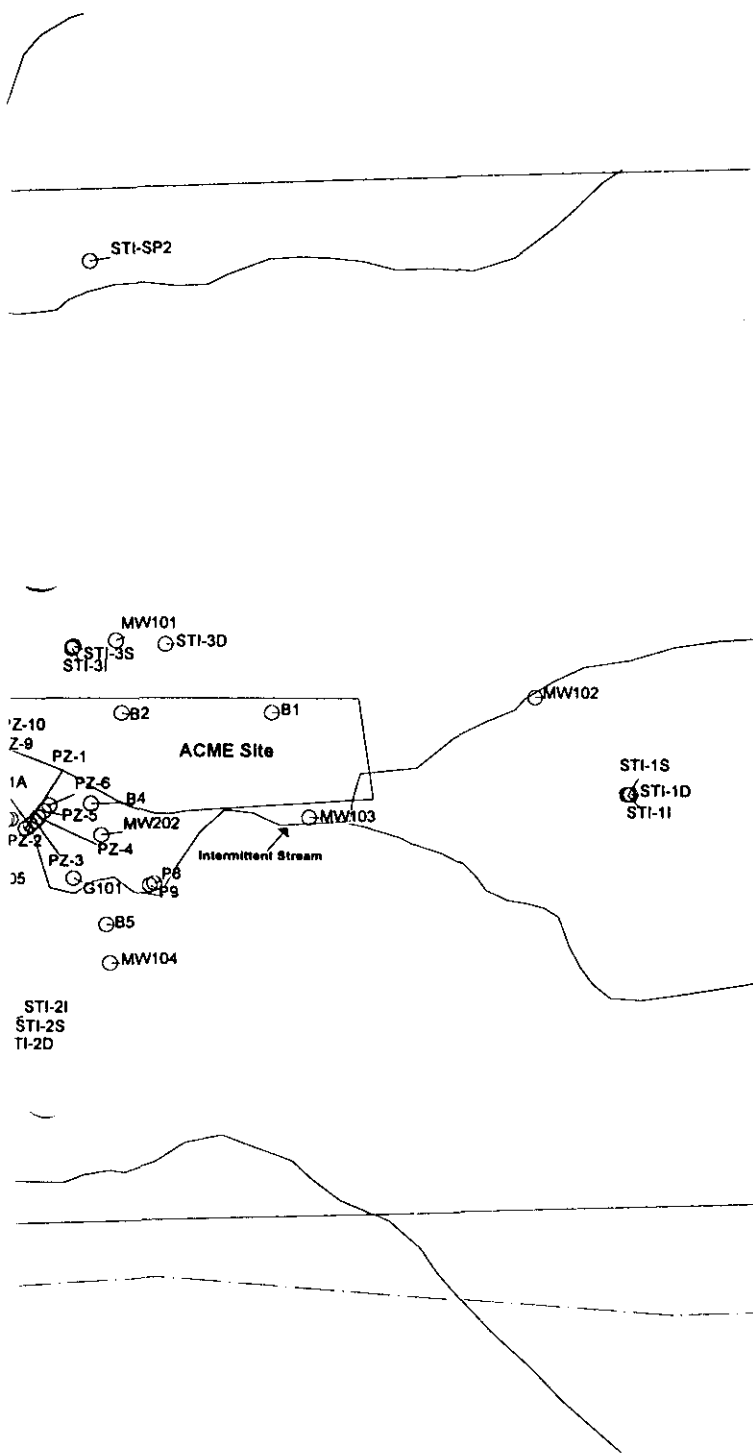
Sand and Gravel Aquifer

Legend

- sand and gravel potentiometric surface
- bedrock potentiometric surface
- bottom of uppermost aquifer




Not drawn to scale

TITLE: GENERALIZED CROSS SECTION OF HYDROGEOLOGIC CONDITIONS AT THE WRL SITE			
LOCATION: Winnebago Reclamation Services, Rockford, IL.			
GeoTrans, Inc. GROUNDWATER SPECIALISTS	CHECKED:	D.B.	FIGURE 2.1
	DRAFTED:	P.K.	
	FILE:	7736001A.D84	
	DATE:	6-28-05	



Winnebago Reclamation Services

Legend

-  Proposed Monitoring Well
-  Existing Stream Gage
-  Existing Monitoring Well

0 1000 2000
feet

TITLE:

Monitoring Well Location Map

LOCATION:

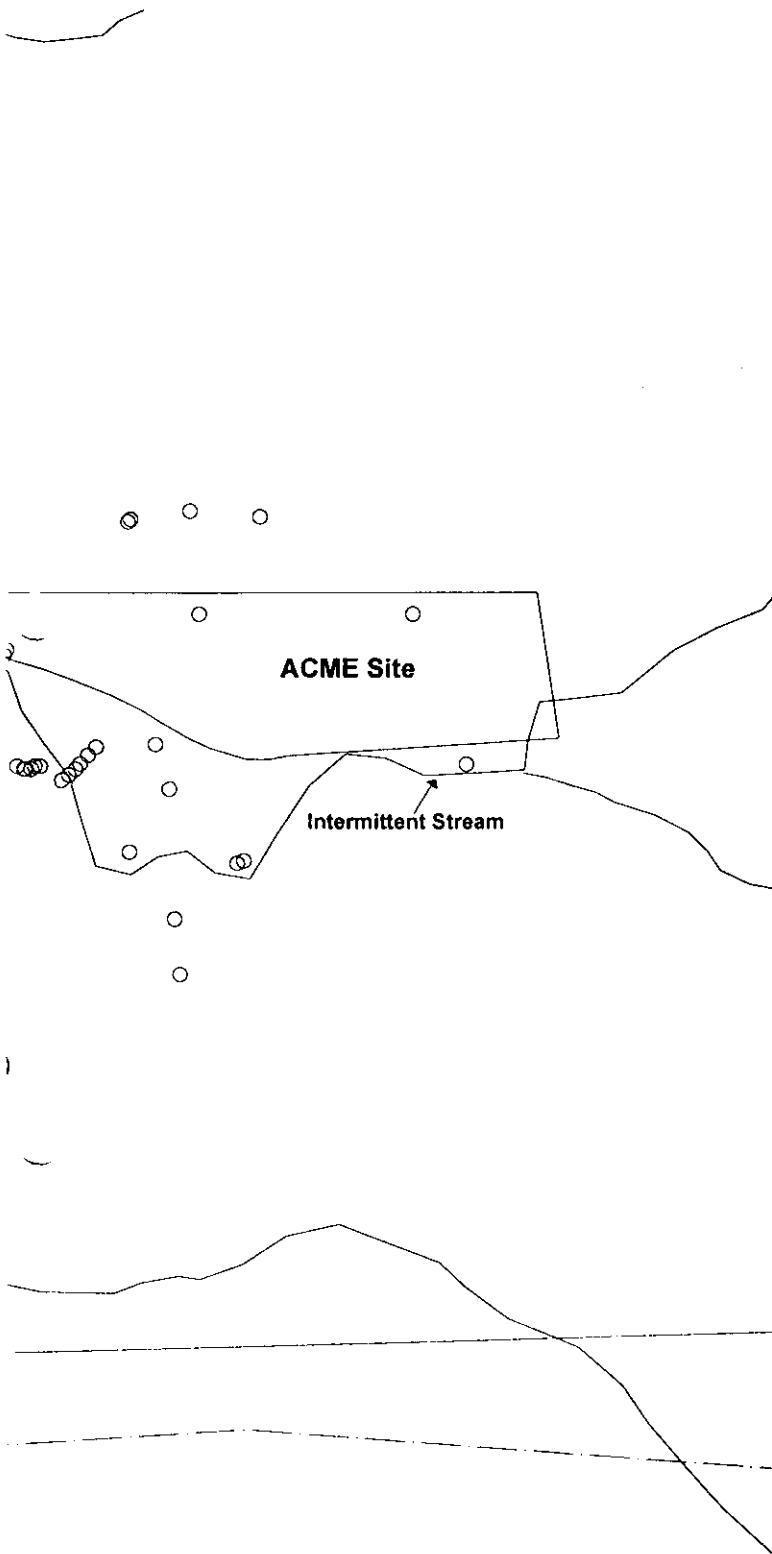
Winnebago Reclamation Services, Rockford, IL.

GeoTrans, inc.

CHECKED:	GCG
DRAFTED:	AV
FILE:	mwlm.wor
DATE:	5-10-95

Figure:

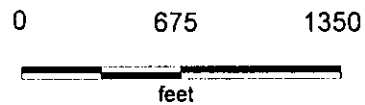
2.2



Winnebago Reclamation Services

Legend

- G101 Well within cross section
- Existing well
- ⊙ Stream Gage
- + Test Boring
- A --- ○ --- A' Cross section transect



TITLE:

Cross Section Location Map

LOCATION:

Winnebago Reclamation Services, Rockford, IL.

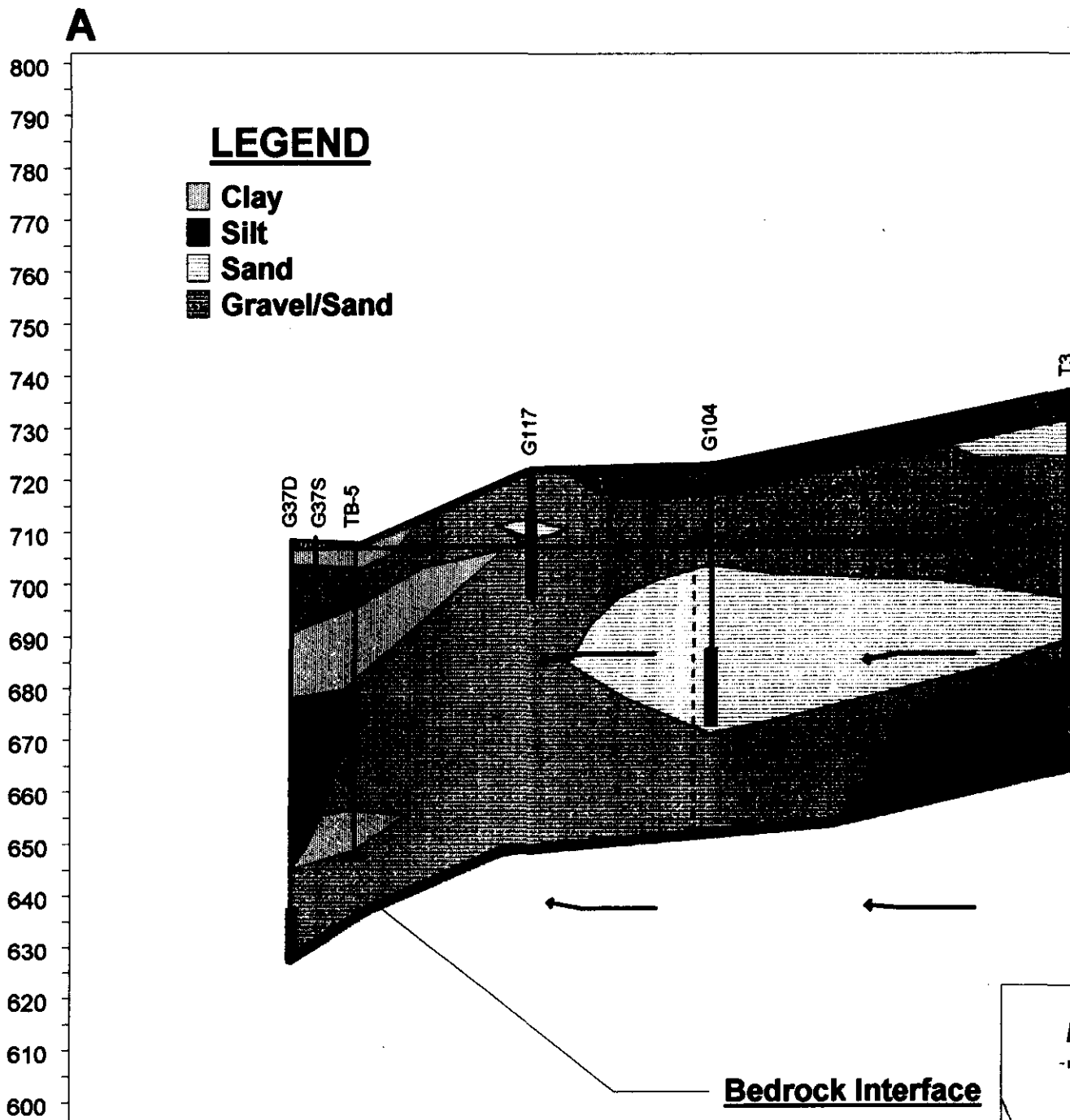
GeoTrans, Inc.

CHECKED:	GCG
DRAFTED:	AV
FILE:	cslm.wor
DATE:	6-26-95

FIGURE:

2-3

\\DATA-winnipeg\gis\work\prof\sa\wor

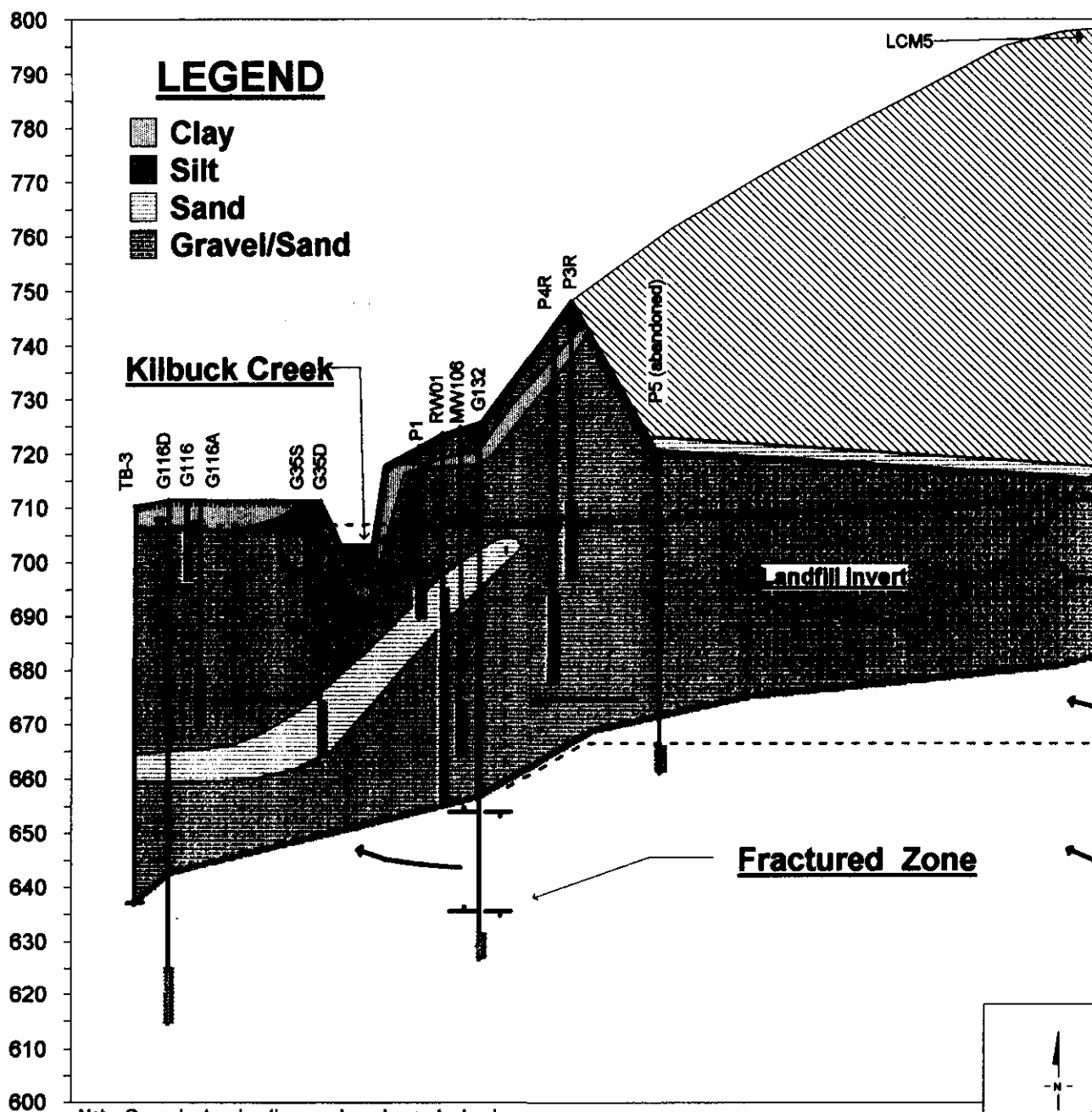


Note: Groundwater elevations are based on water level data collected on 02/17/95.

The distances between boring locations were estimated based on straight-line transects.

—▽— Upper Sand and Gravel Aquifer Potentiometric Surface
- - -▽ - - - Bedrock Aquifer Potentiometric Surface
← Groundwater Flow Direction

B



Note: Groundwater elevations are based on water level data collected on 02/17/95.

The distances between boring locations were estimated based on straight-line transects.

- Upper Sand and Gravel Aquifer Potentiometric Surface
- Bedrock Aquifer Potentiometric Surface
- Groundwater Flow Direction



Vertical Exaggeration = 10X

C

800
790
780
770
760
750
740
730
720
710
700
690
680
670
660
650
640
630
620
610
600

LEGEND

- Clay
- Silt
- Sand
- Gravel/Sand

Kilbuck Creek

TB-1
G33D
G33S

G36
TB-4

G106
G115

E4A
E4

Bedrock Interface

Note: Groundwater elevations are based on water level data collected on 02/17/95.

The distances between boring locations were estimated based on straight-line transects.

- Upper Sand and Gravel Aquifer Potentiometric Surface
- Bedrock Aquifer Potentiometric Surface
- Groundwater Flow Direction



Vertical Exaggeration = 10X

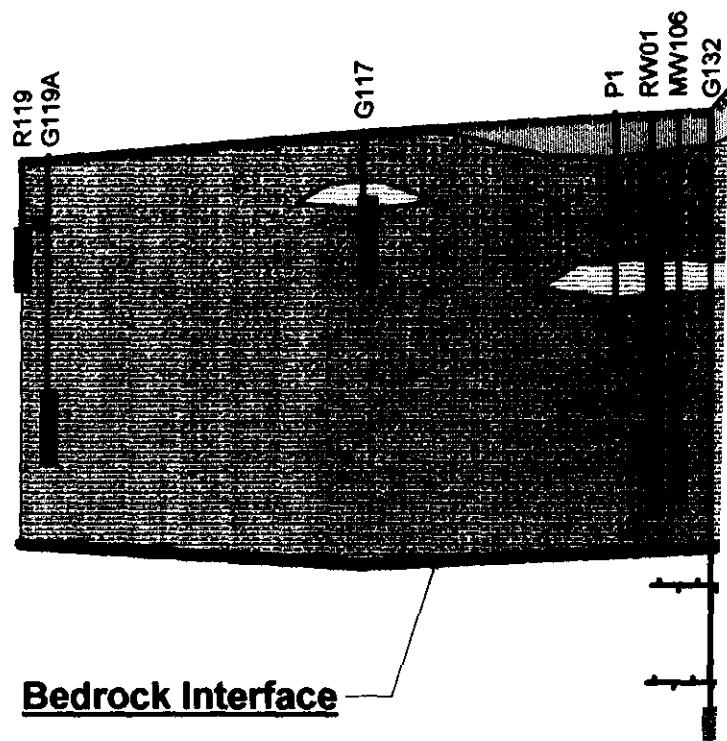
\\DATA-winnipeg\gis\work\profcc.wor

\\DATA-winnabago\gis\work\profdd.wor

D
800
790
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770
760
750
740
730
720
710
700
690
680
670
660
650
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630
620
610
600

LEGEND

-  Clay
-  Silt
-  Sand
-  Gravel/Sand

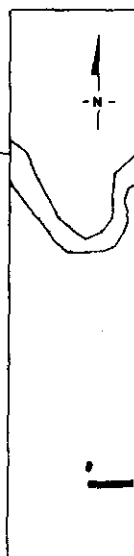


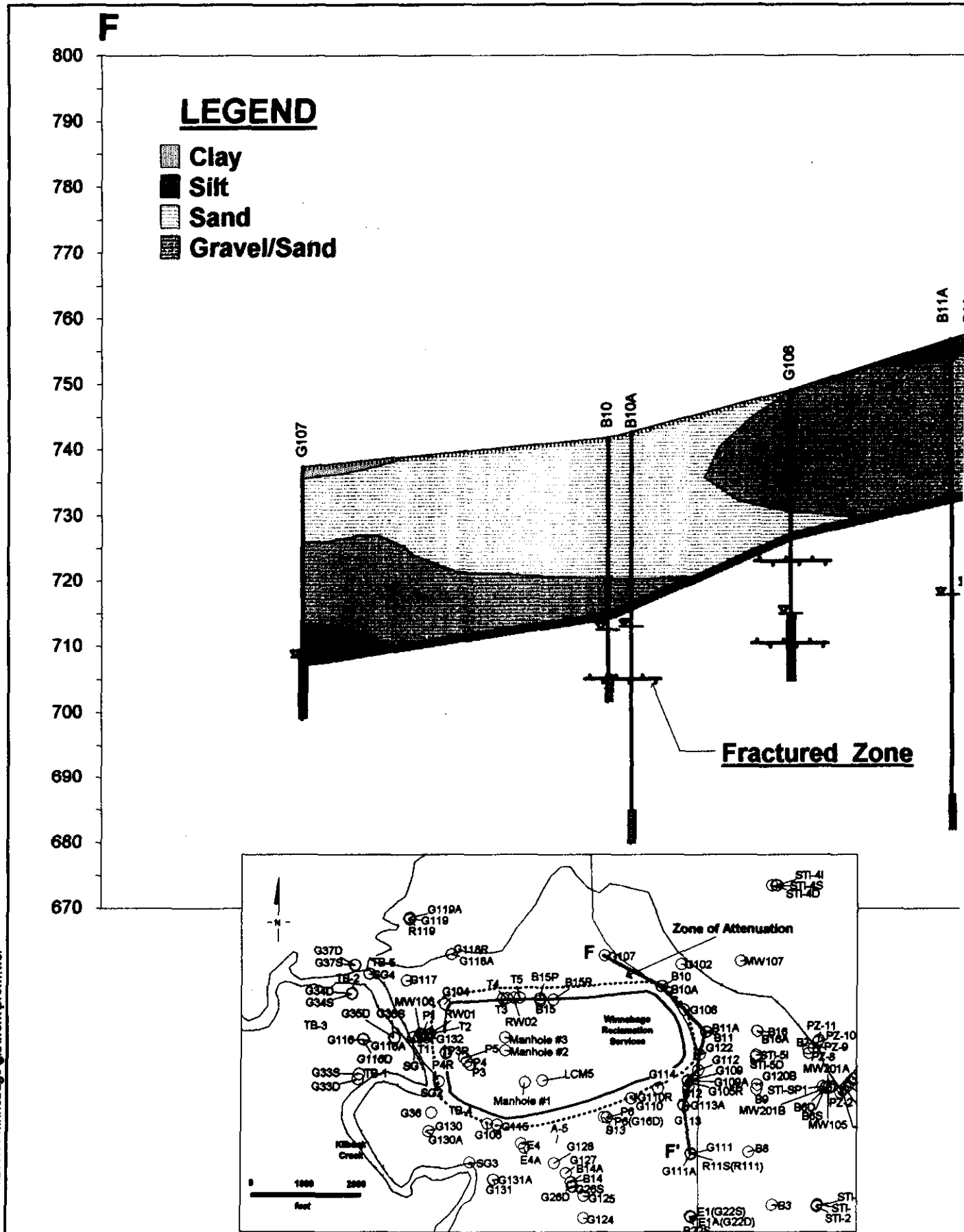
Note: Groundwater elevations are based on water level data collected on 02/17/95.

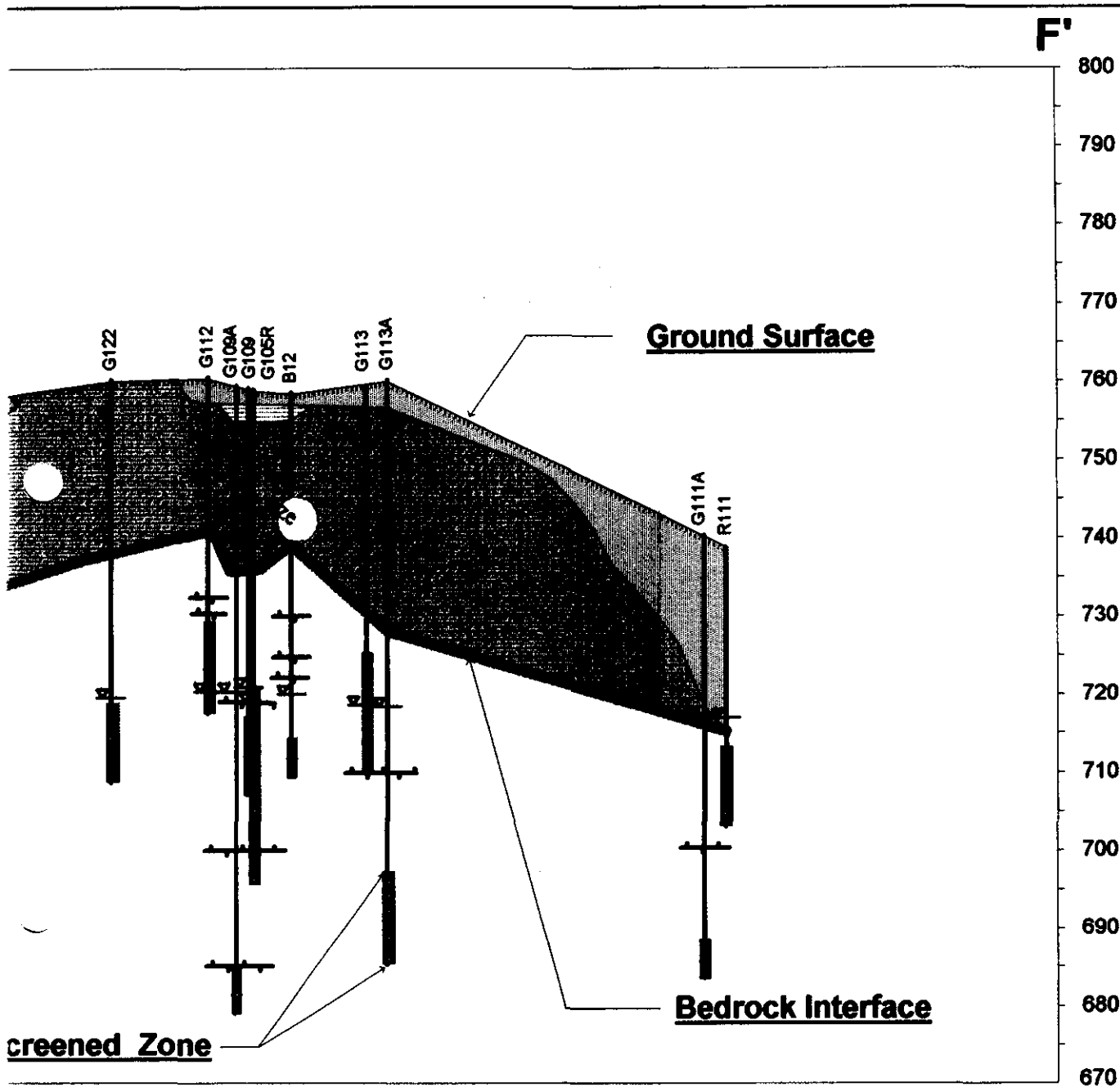
The distances between boring locations were estimated based on straight-line transects.



Vertical Exaggeration = 10X





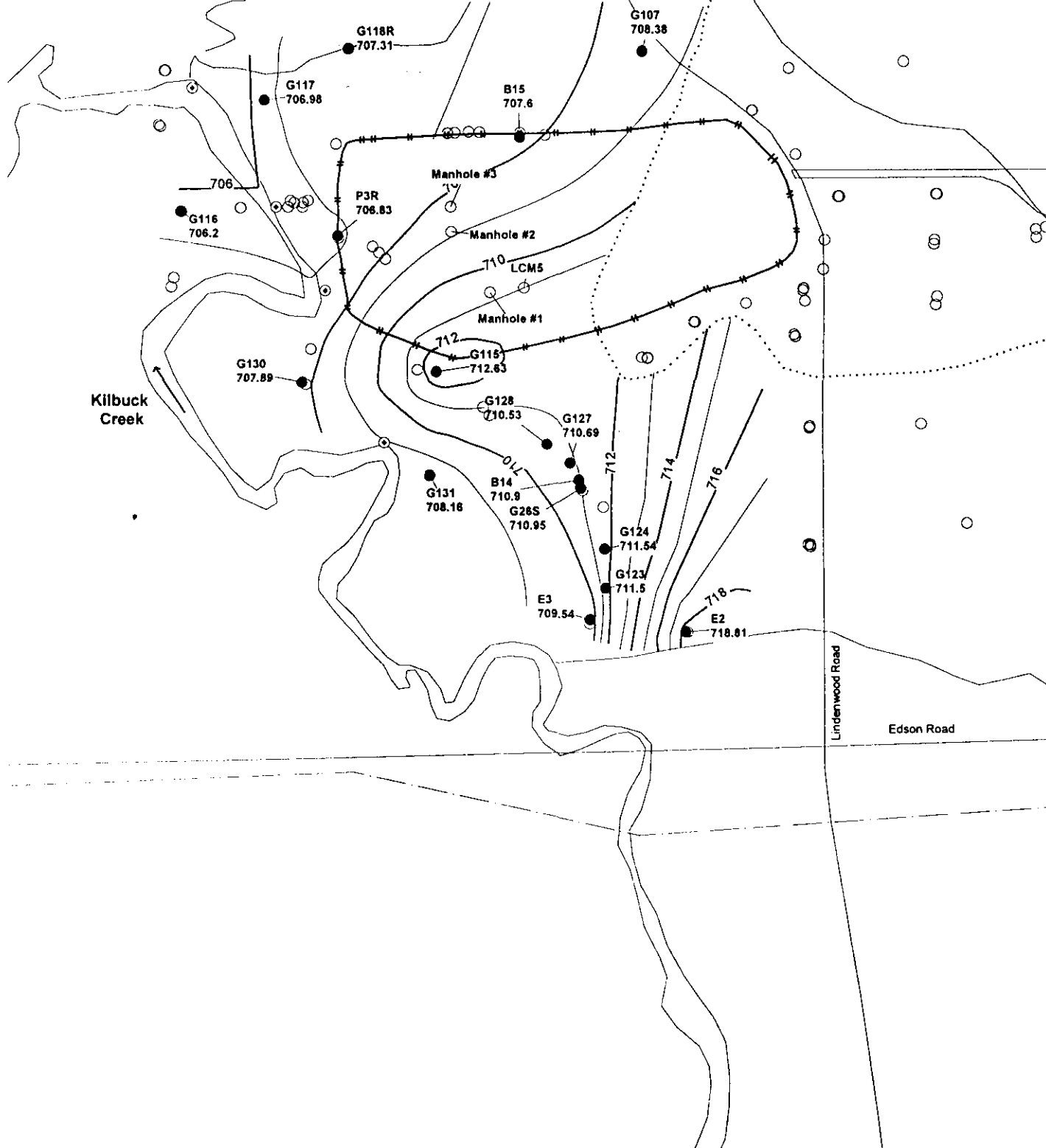


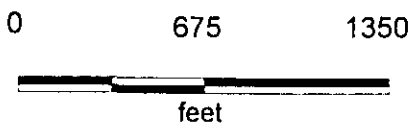
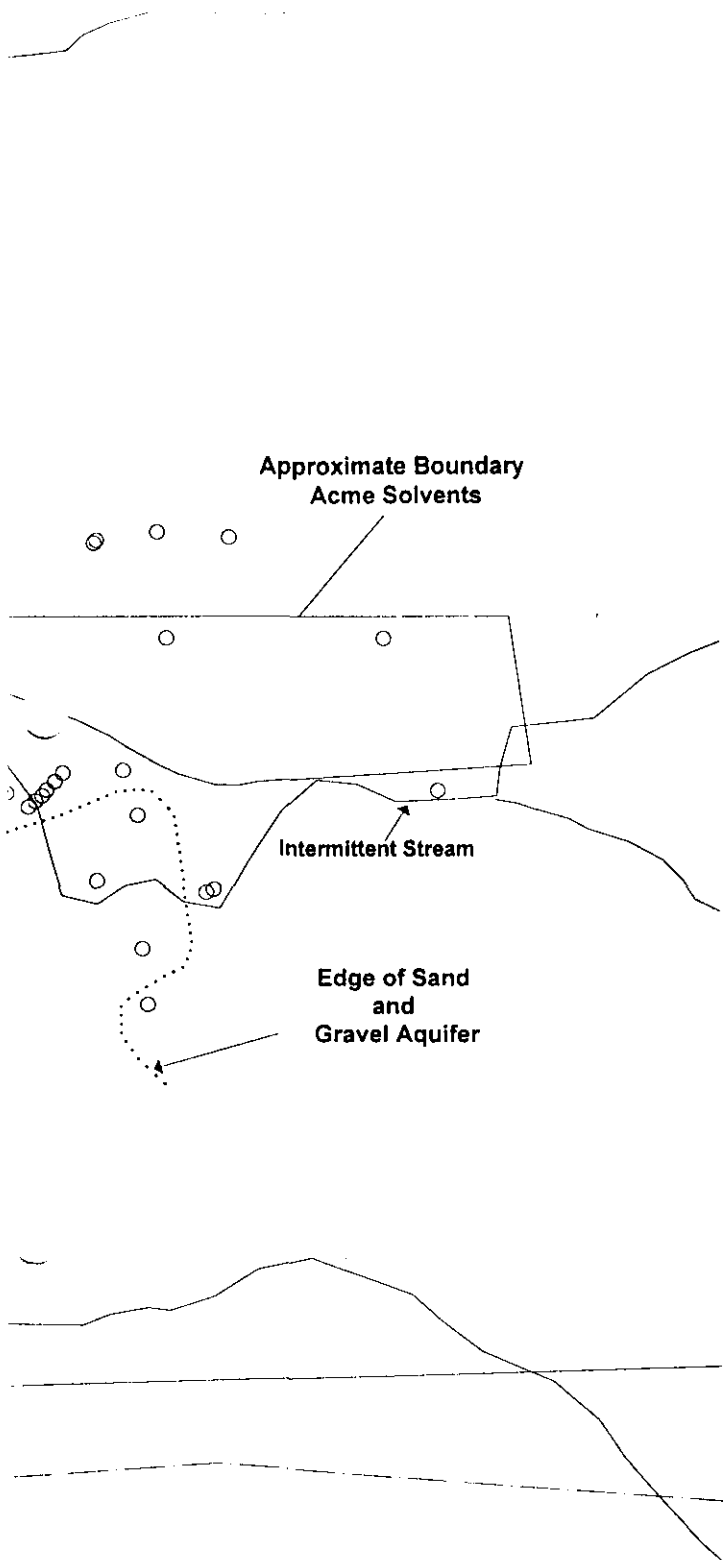
Note: Groundwater elevations are based on water level data collected on 02/17/95.

The distances between boring locations were estimated based on straight-line transects.

GeoTrans, Inc.	Winnebago Reclamation Service, Inc.	
Profile F-F'		
PREPARED BY: STG	DATE: 09 MAY 95	FIGURE 2.9
CHECKED BY: DKB	REVISED: 12 JUNE 95	
DRAWN BY: STG	WRKSPC: PROFF.F.WOR	

Approximate Limit
Waste Disposal
Winnebago Reclamation Landfill





Winnebago Reclamation Services

LEGEND

- Monitoring Well
- G101 Well I.D. and Groundwater 750.90 Elevation
- ⊙ SG3 Stream Gage I.D.
- ~~~~~ 750 Groundwater Elevation Contours
- - - Intermittent Stream
- Edge of Sand and Gravel Aquifer

TITLE: Groundwater Elevation Contours
Upper Zone of the Sand and Gravel Aquifer
(7/12/94)

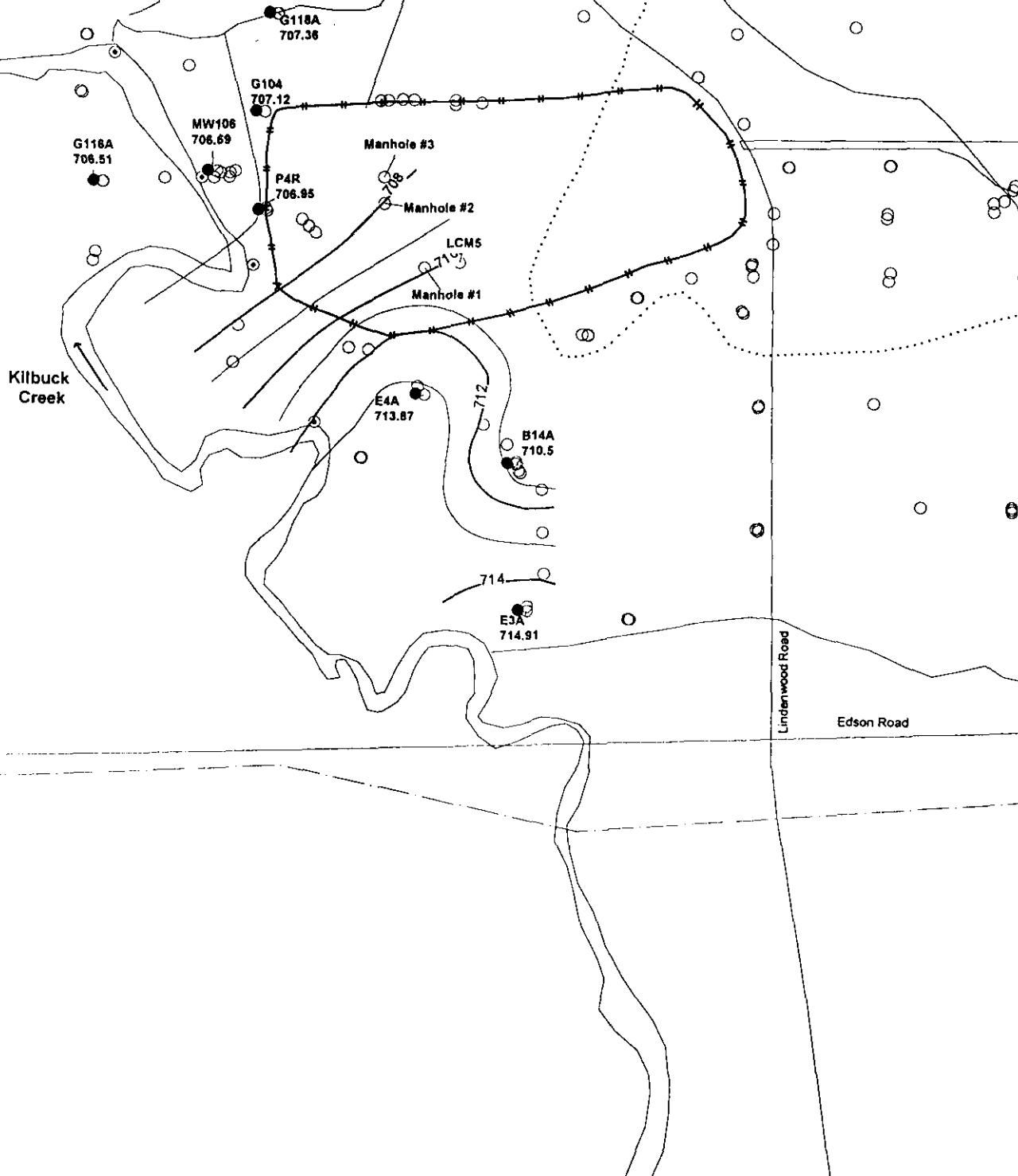
LOCATION: Winnebago Reclamation Services, Rockford, IL.

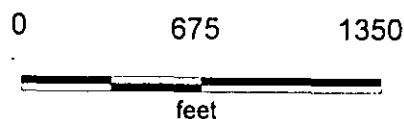
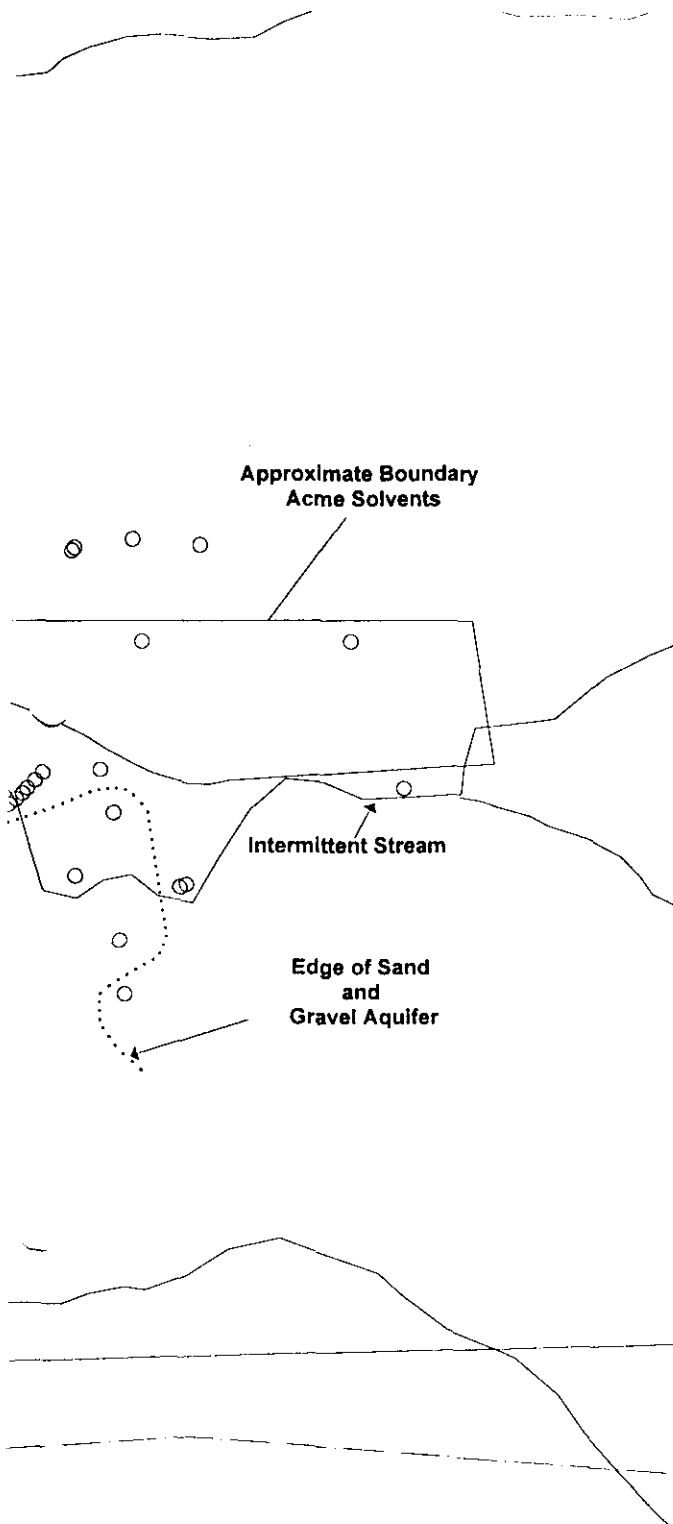
GeoTrans, inc.

CHECKED:	DB
DRAFTED:	ELA
FILE:	HR 39.WOR
DATE:	9 MAY 1995

FIGURE:
2.10

Approximate Limit
Waste Disposal
Winnebago Reclamation Landfill





Winnebago Reclamation Services

LEGEND

- Monitoring Well
- G101 Well I.D. and Groundwater 750.90 Elevation
- ⊙ SG3 Stream Gage I.D.
- 750 Groundwater Elevation Contours
- Intermittent Stream
- ... Edge of Sand and Gravel Aquifer

TITLE: Groundwater Elevation Contours
Lower Zone of the Sand and Gravel Aquifer
(7/12/94)

LOCATION: Winnebago Reclamation Services, Rockford, IL.

GeoTrans, inc.

CHECKED:	DB
DRAFTED:	ELA
FILE:	HR_310.WOR
DATE:	9 MAY 1995

FIGURE:
2.11

Approximate Limit
Waste Disposal
Winnebago Reclamation Landfill

Kilbuck
Creek

Edson Road

Lindenwood Road

B15P
707.92

Manhole #3

Manhole #2

LCMS

Manhole #1

G130A
707.93

G131A
710.00

B13
713.06

E2A
714.02

G110
714.33

G114
717.11

B12
718.47

G105R
718.50

G112
718.99

G122
719.22

B11
717.89

G108
714.04

B10
712.14

B16
720.92

B9
720.08

B8
719.87

G111
718.18

G113
717.62

G116
718.47

G117
717.11

G118
718.47

G119
718.47

G120
718.47

G121
718.47

G122
718.47

G123
718.47

G124
718.47

G125
718.47

G126
718.47

G127
718.47

G128
718.47

G129
718.47

G130
718.47

G131
718.47

G132
718.47

G133
718.47

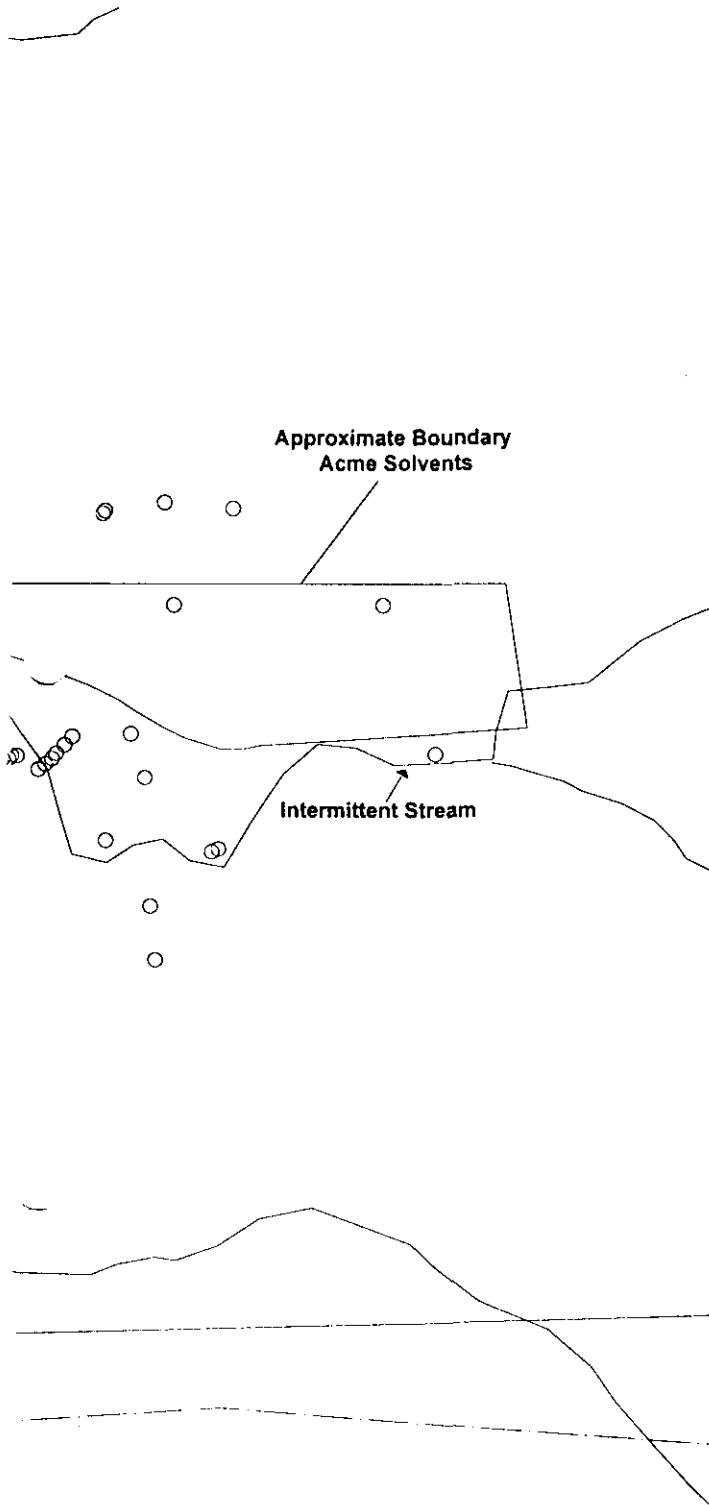
G134
718.47

G135
718.47

G136
718.47

G137
718.47

G138
718.47

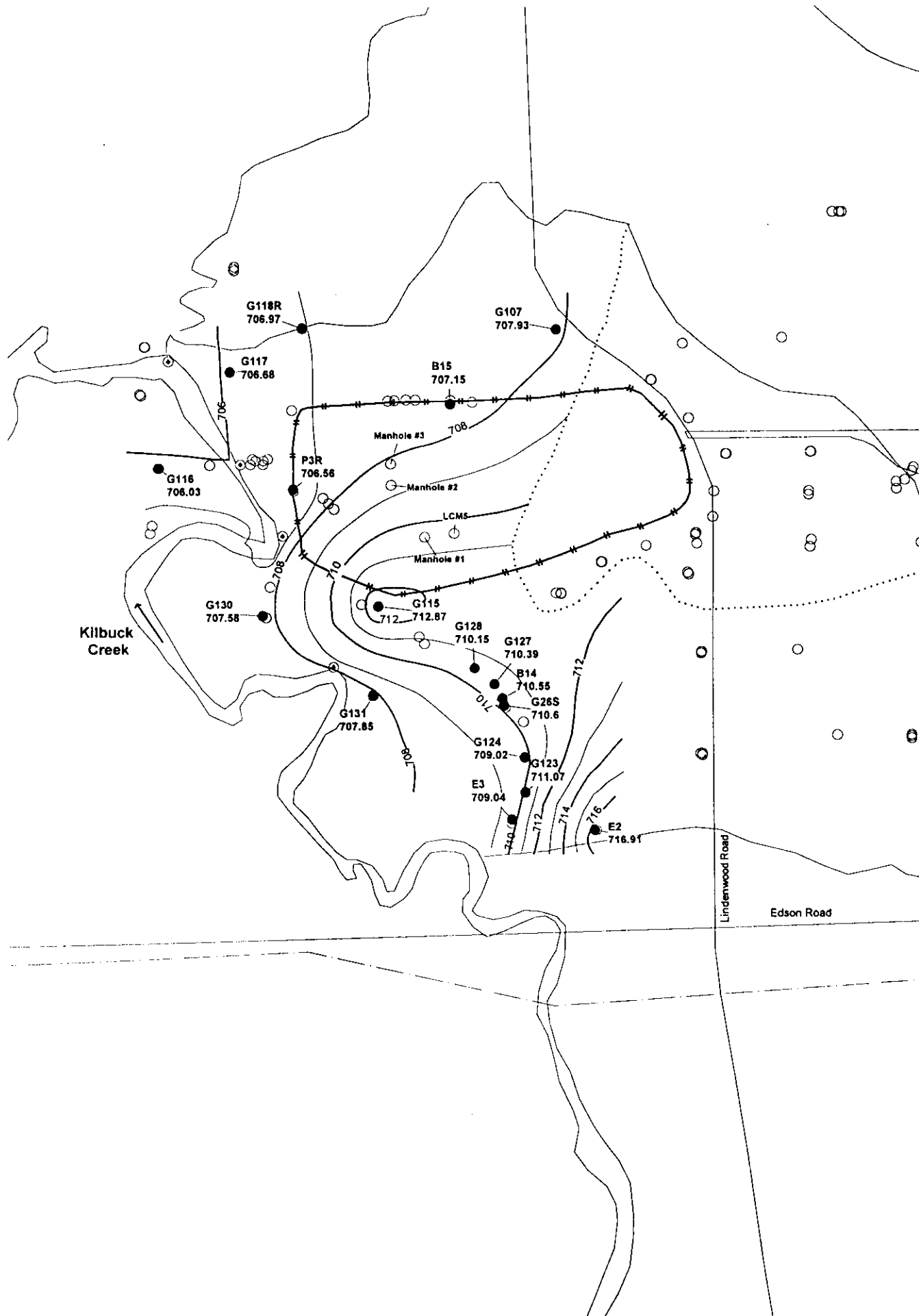


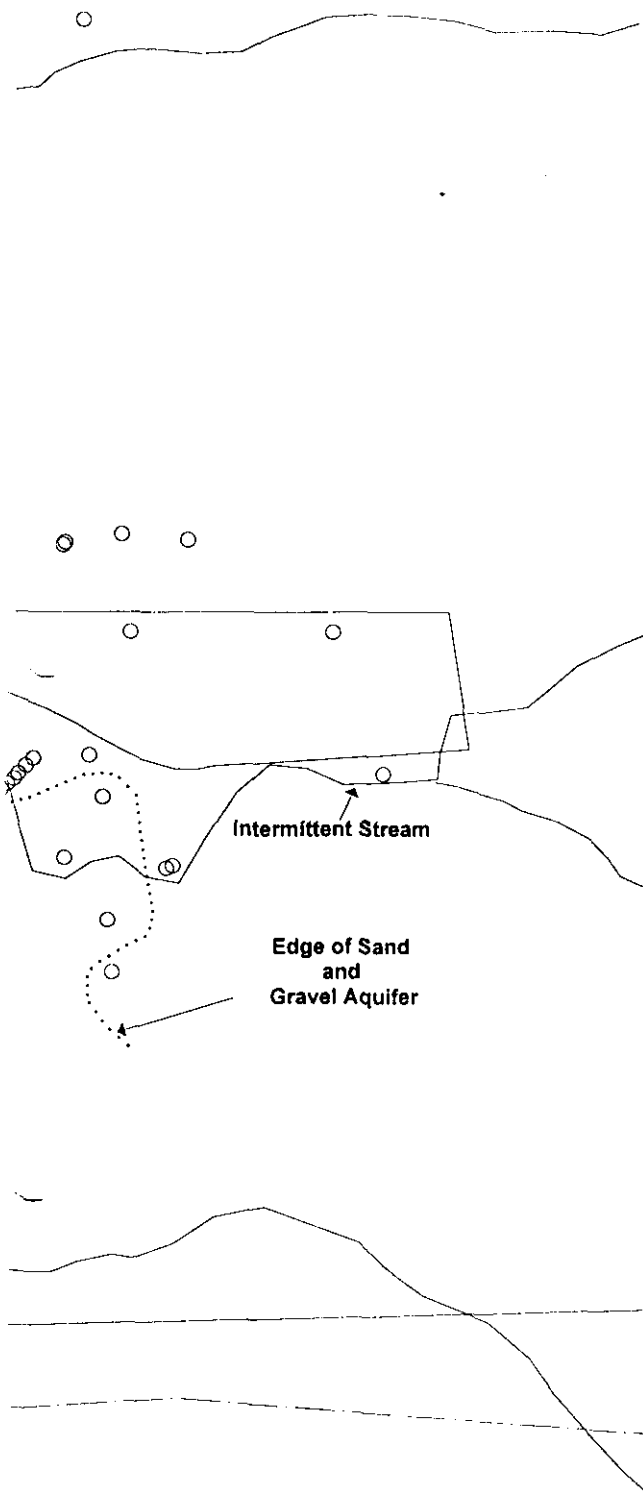
Winnebago Reclamation Services

LEGEND

- Monitoring Well
- G101 Well I.D. and Groundwater
750.90 Elevation
- ⊙ SG3 Stream Gage I.D.
- ~~~~~ 750 Groundwater Elevation Contours
- ~~~~~ Intermittent Stream
- Edge of Sand and Gravel Aquifer

TITLE: Groundwater Elevation Contours Shallow Zone of the Galena-Platteville Dolomite Aquifer (7/12/94)			
LOCATION: Winnebago Reclamation Services, Rockford, IL.			
GeoTrans, inc.	CHECKED:	DB	FIGURE: 2.12
	DRAFTED:	ELA	
	FILE:	HR_311.WOR	
	DATE:	9 MAY 1995	





Winnebago Reclamation Services

LEGEND

- Monitoring Well
- G101 Well I.D. and Groundwater 750.90 Elevation
- ⊙ SG3 Stream Gage I.D.
- 750 Groundwater Elevation Contours
- Intermittent Stream
- ... Edge of Sand and Gravel Aquifer

0 675 1350
feet

TITLE: Groundwater Elevation Contours
Upper Zone of the Sand and Gravel Aquifer
(9/19/94)

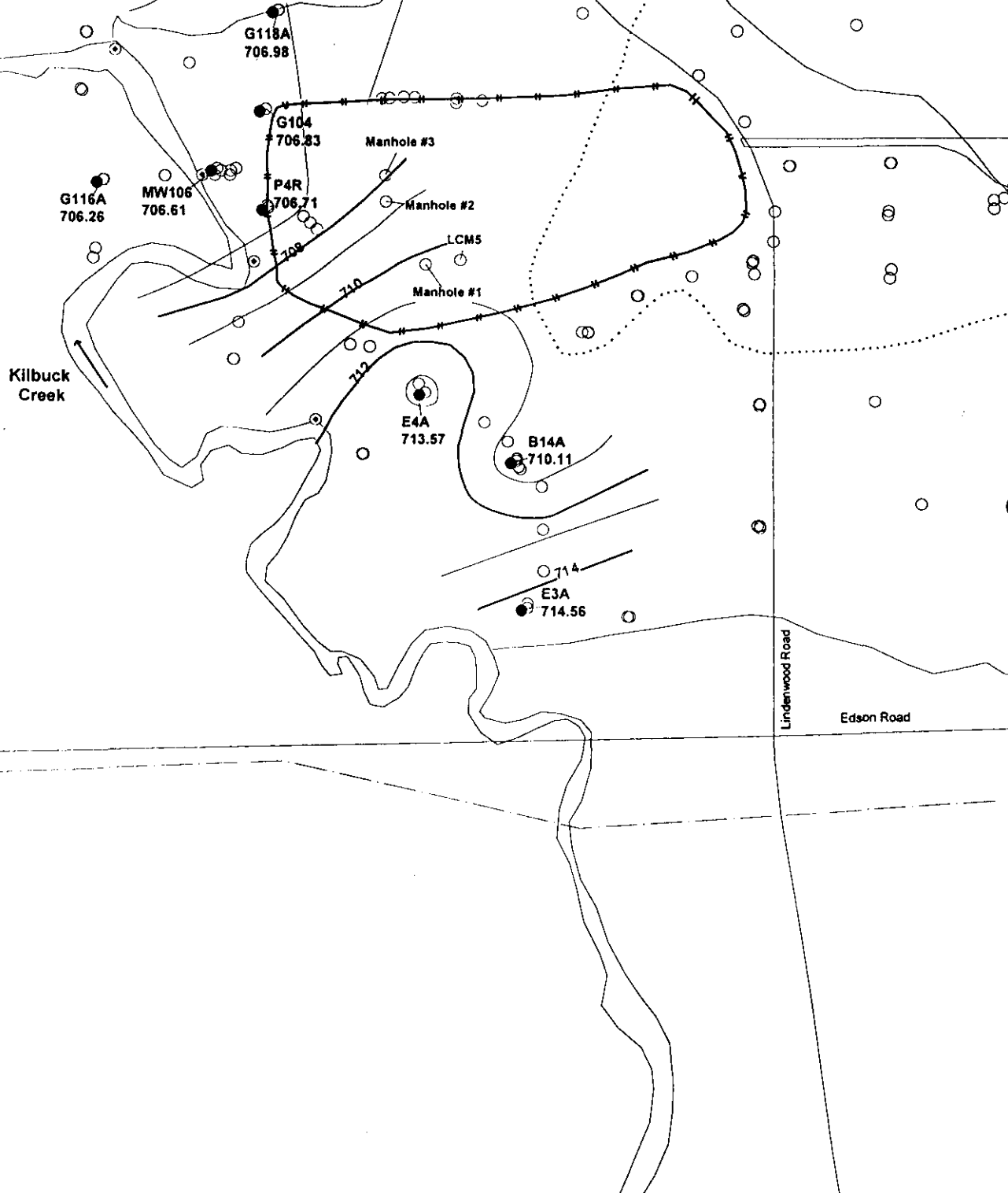
LOCATION:
Winnebago Reclamation Services, Rockford, IL.

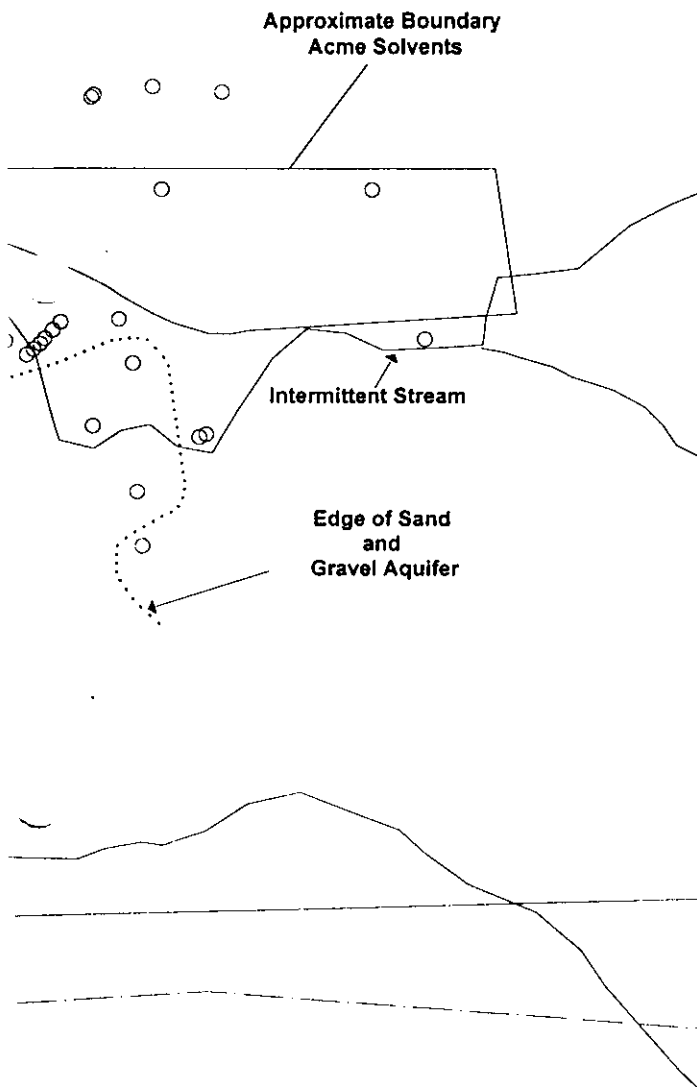
GeoTrans, inc.

CHECKED:	DB
DRAFTED:	ELA
FILE:	HR_312.WOR
DATE:	9 MAY 1995

FIGURE:
2.13

Approximate Limit
Waste Disposal
Winnebago Reclamation Landfill





0 675 1350
feet



Winnebago Reclamation Services

LEGEND

- Monitoring Well
- G101 Well I.D. and Groundwater
750.90 Elevation
- ⊙ SG3 Stream Gage I.D.
- ~~~~~ 750 Groundwater Elevation Contours
- ~~~~~ Intermittent Stream
- Edge of Sand and Gravel Aquifer

TITLE: Groundwater Elevation Contours
Lower Zone of the Sand and Gravel Aquifer
(9/19/94)

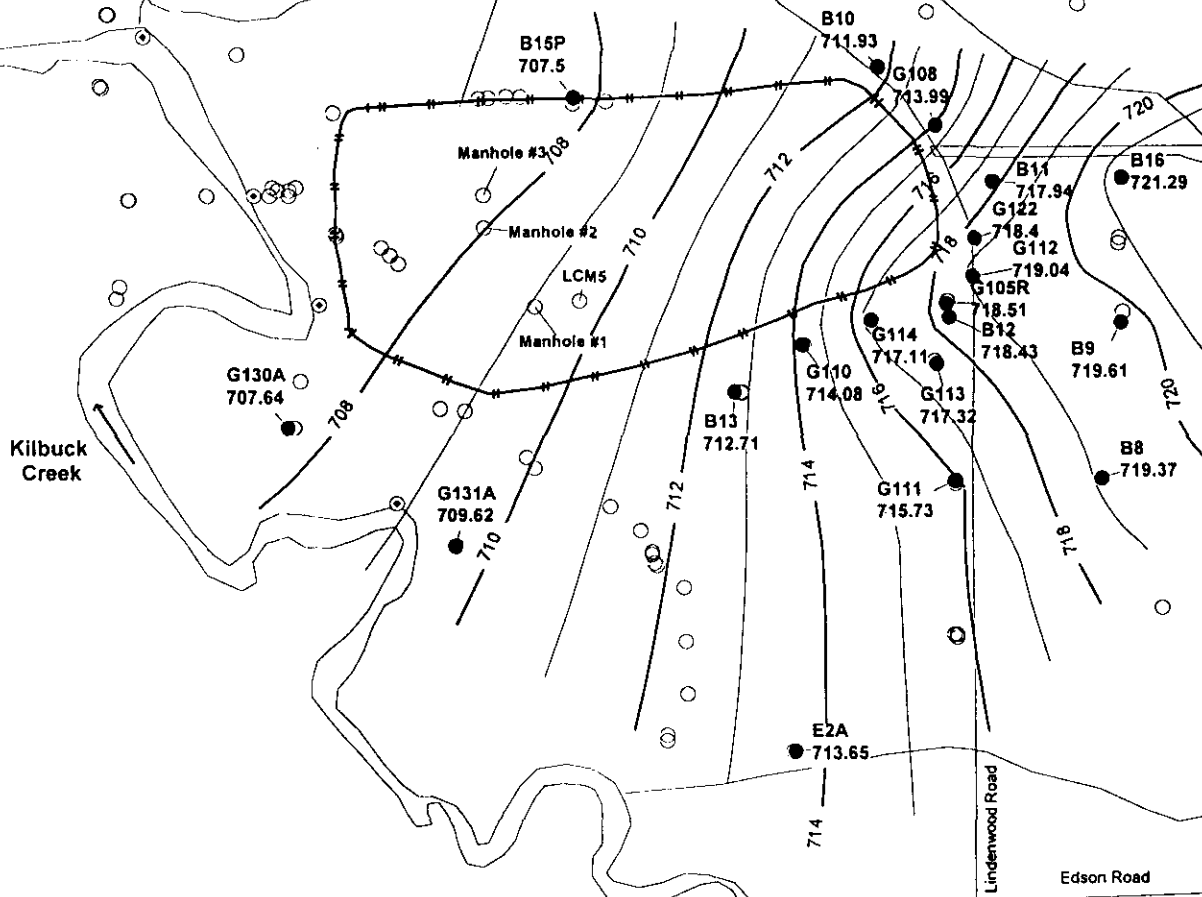
LOCATION: Winnebago Reclamation Services, Rockford, IL.

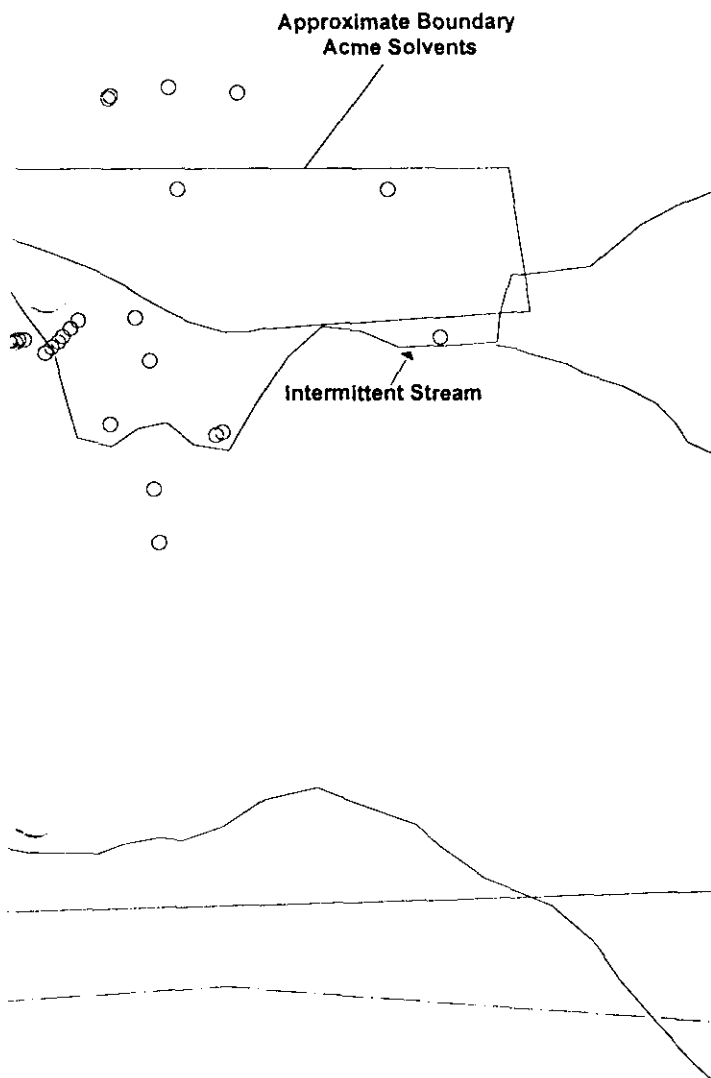
GeoTrans, inc.

CHECKED:	DB
DRAFTED:	ELA
FILE:	HR_313.WOR
DATE:	9 MAY 1995

FIGURE:
2.14

Approximate Limit
Waste Disposal
Winnebago Reclamation Landfill





Winnebago Reclamation Services

LEGEND

- Monitoring Well
- G101 Well I.D. and Groundwater
750.90 Elevation
- ⊙ SG3 Stream Gage I.D.
- 750 Groundwater Elevation Contours
- Intermittent Stream
- Edge of Sand and Gravel Aquifer

TITLE: Groundwater Elevation Contours
Shallow Zone of Galena-Platteville
Dolomite Aquifer (9/19/94)

LOCATION: Winnebago Reclamation Services, Rockford, IL.

GeoTrans, inc.

CHECKED:	DB
DRAFTED:	ELA
FILE:	HR_314.WOR
DATE:	9 MAY 1995

FIGURE:
2.15

Approximate Limit
Waste Disposal
Winnebago Reclamation Landfill

Kilbuck
Creek

Lindenwood Road

Edson Road

G119
706.91

G118R
707.31

G107
708.38

SG4

G117
707.08

B15
707.55

P1
706.79

G116
706.25

SG1

P1R
706.78

Manhole #3

Manhole #2

LCM5

Manhole #1

712

G115
713.18

G130
708.09

SG3

G131
708.46

B14
711.3

G128
710.83

G265
711.4

G124
711.94

E3
709.94

G127
711.19

714

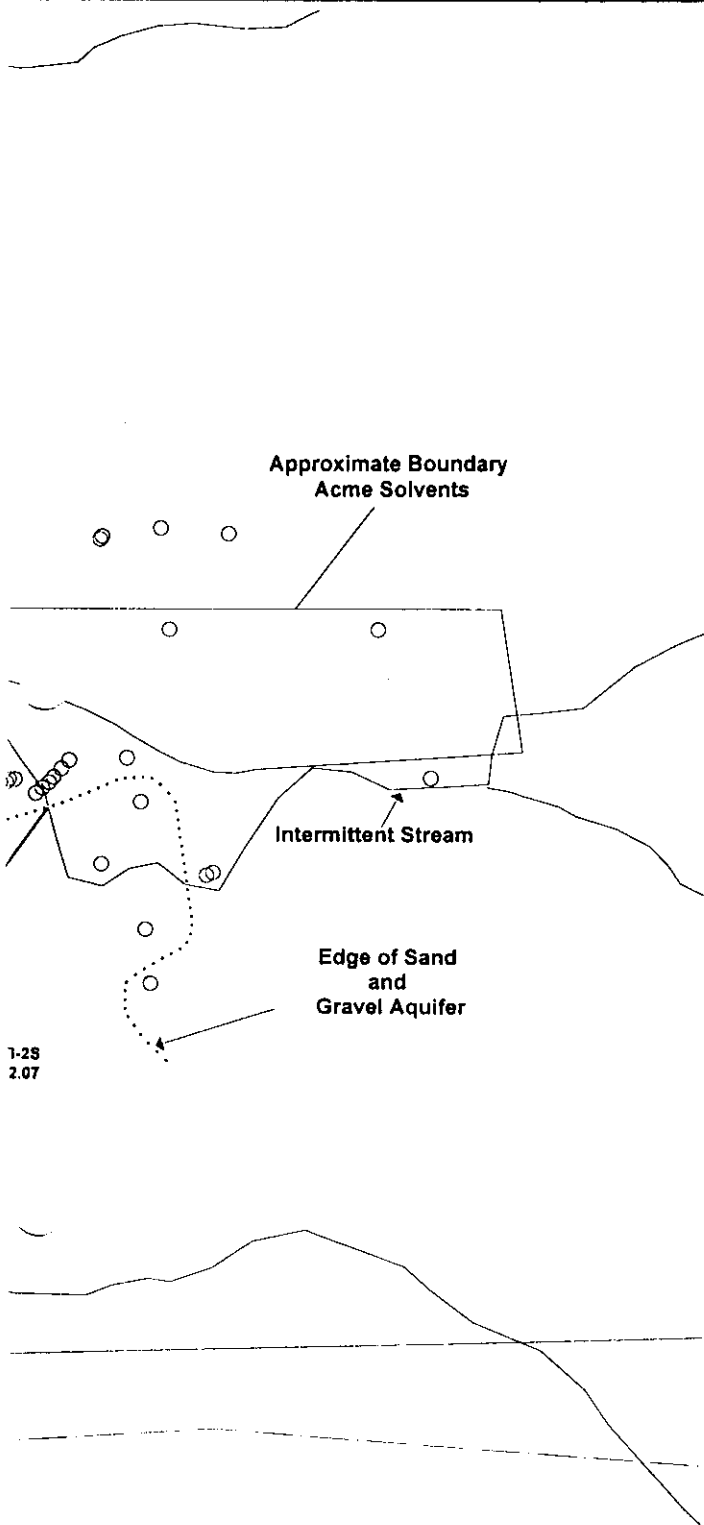
716

718

720

E2
720.06

722



Winnebago Reclamation Services

LEGEND

- Monitoring Well
- G101 Well I.D. and Groundwater
750.90 Elevation
- ⊙ SG3 Stream Gage I.D.
- 750 Groundwater Elevation Contours
- Intermittent Stream
- Edge of Sand and Gravel Aquifer

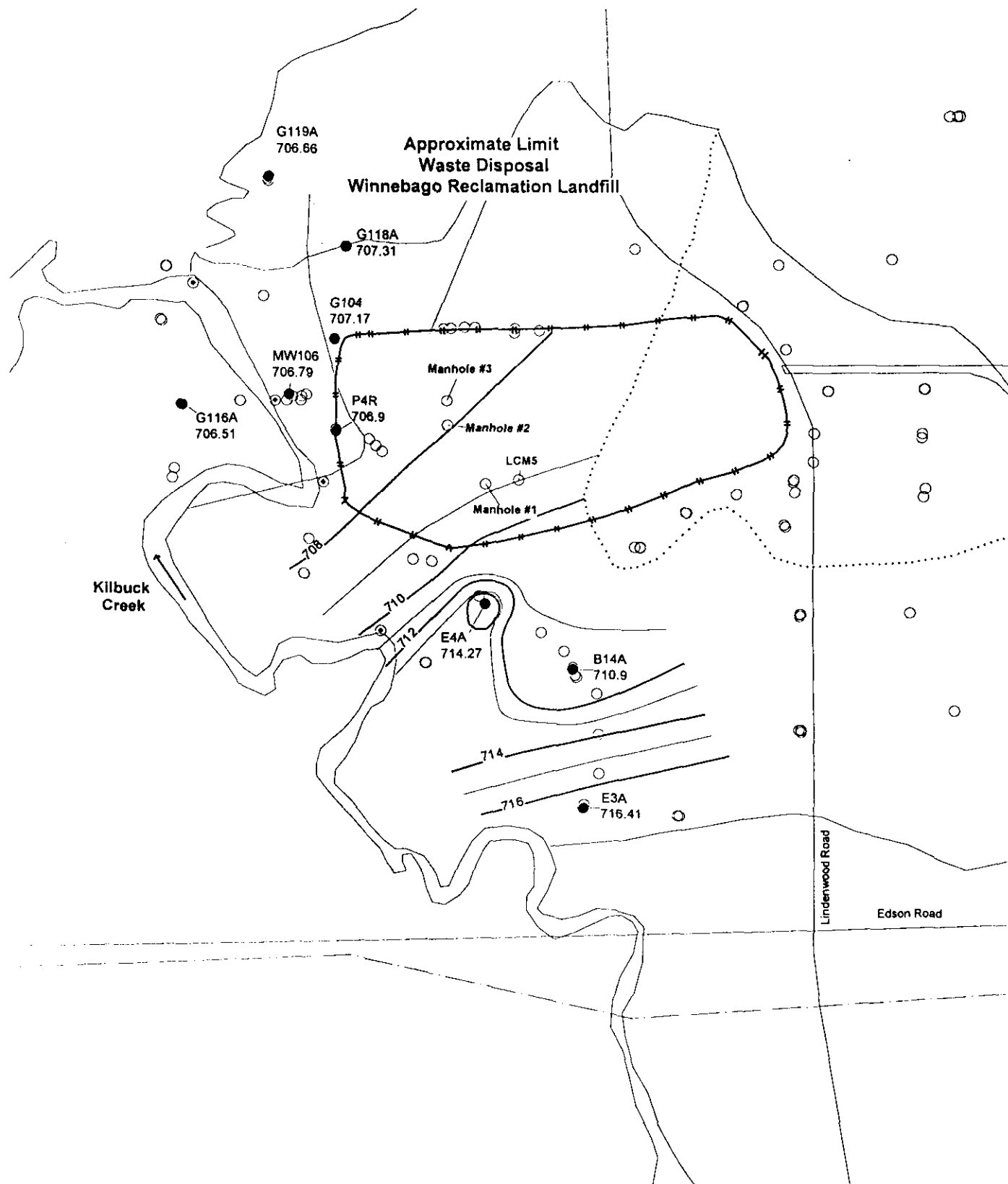
TITLE: Groundwater Elevation Contours
Upper Zone of the Sand and Gravel Aquifer
(2/17/95)

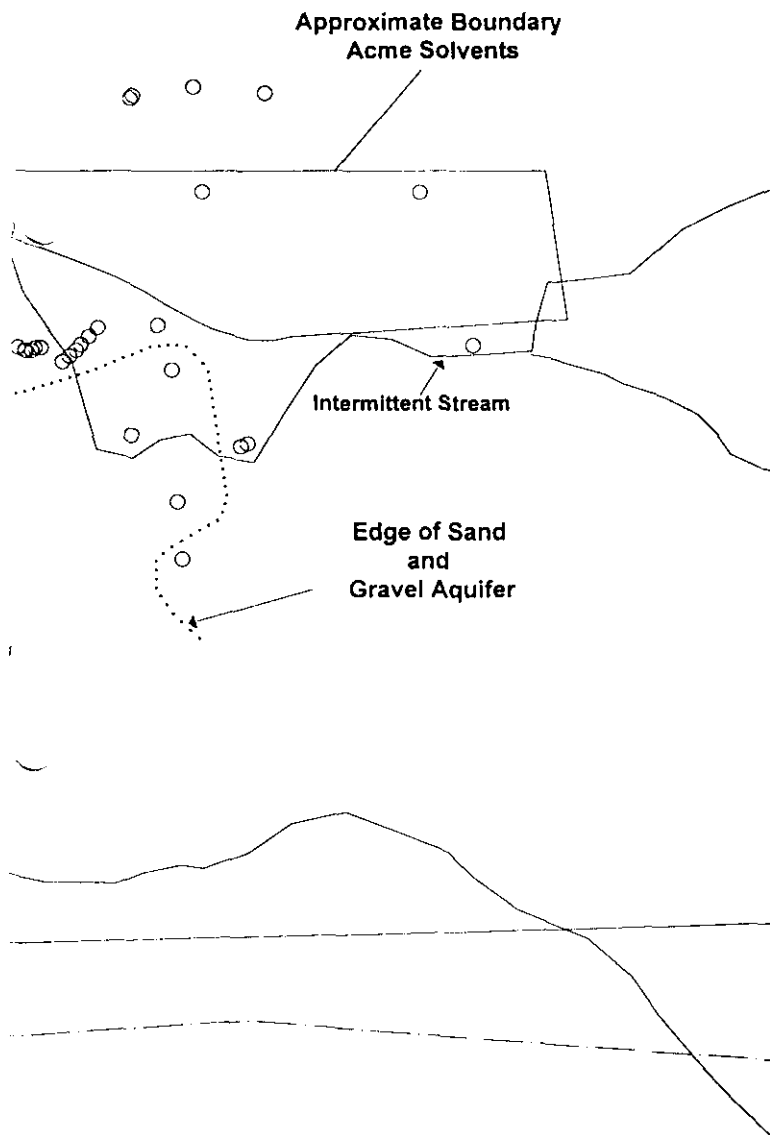
LOCATION: Winnebago Reclamation Services, Rockford, IL.

GeoTrans, inc.

CHECKED:	DB
DRAFTED:	ELA
FILE:	HR_315.WOR
DATE:	9 MAY 1995

FIGURE:
2.16





0 675 1350



Winnebago Reclamation Services

LEGEND

- Monitoring Well
- G101 Well I.D. and Groundwater 750.90 Elevation
- ⊙ SG3 Stream Gage I.D.
- 750 Groundwater Elevation Contours
- ~ Intermittent Stream
- - - Edge of Sand and Gravel Aquifer

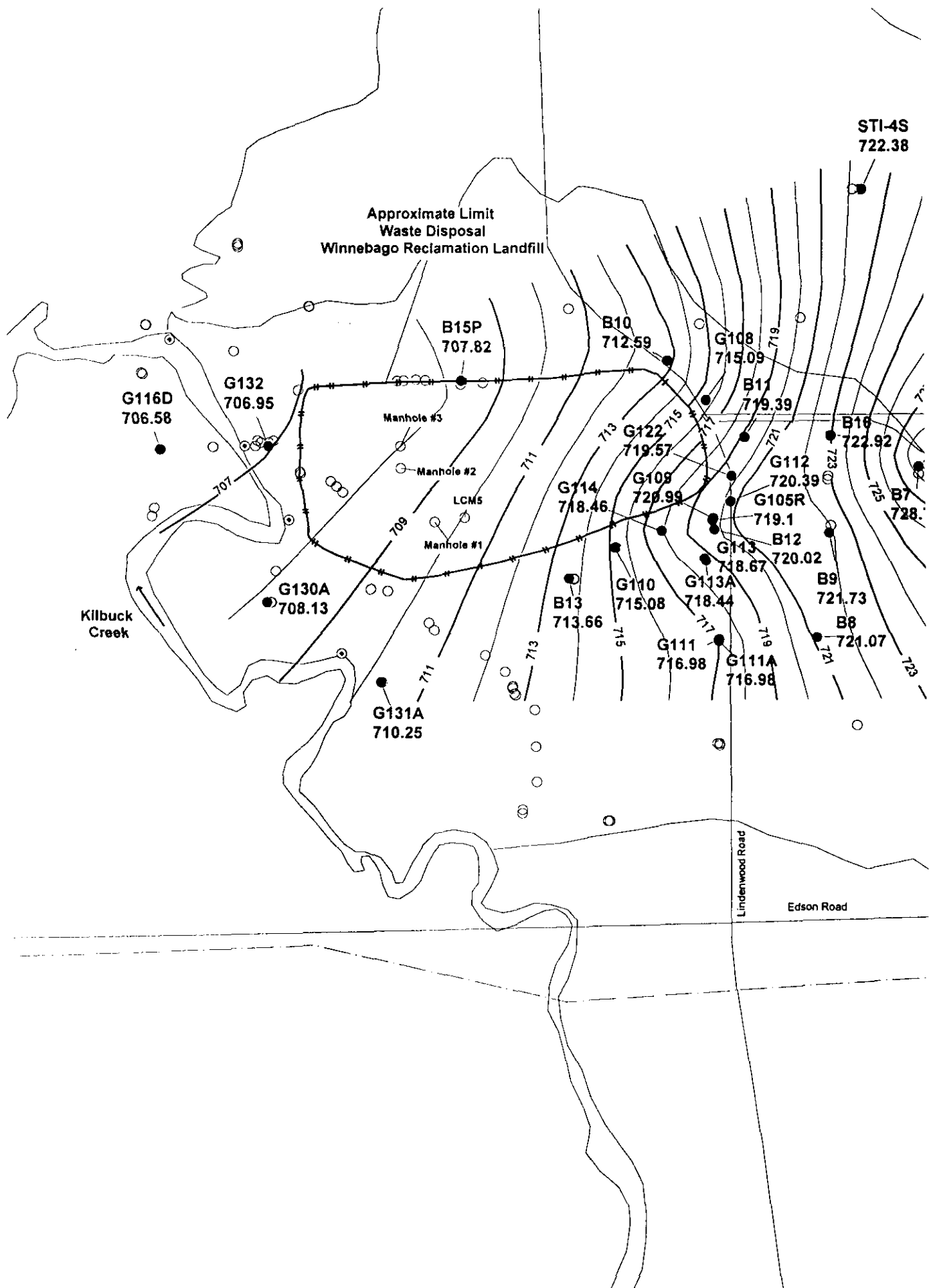
TITLE: Groundwater Elevation Contours
Lower Zone of the Sand and Gravel Aquifer
(2/17/95)

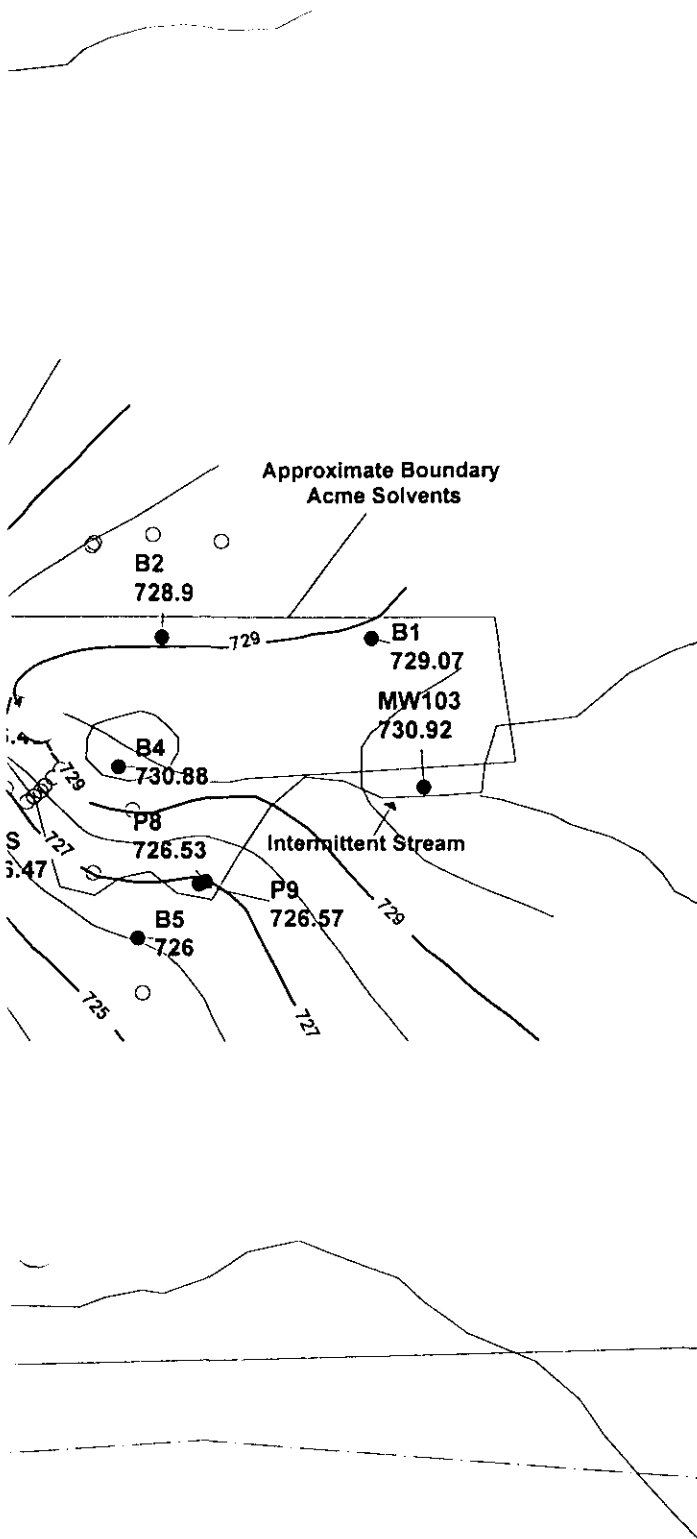
LOCATION: Winnebago Reclamation Services, Rockford, IL.

GeoTrans, inc.

CHECKED:	DB
DRAFTED:	ELA
FILE:	HR_316.WOR
DATE:	9 MAY 1995

FIGURE:
2.17





N

Winnebago Reclamation Services

LEGEND

- Monitoring Well
- G101 Well I.D. and Groundwater
750.90 Elevation
- ⊙ SG3 Stream Gage I.D.
- 750 Groundwater Elevation Contours
- Intermittent Stream
- Edge of Sand and Gravel Aquifer

0 675 1350
feet

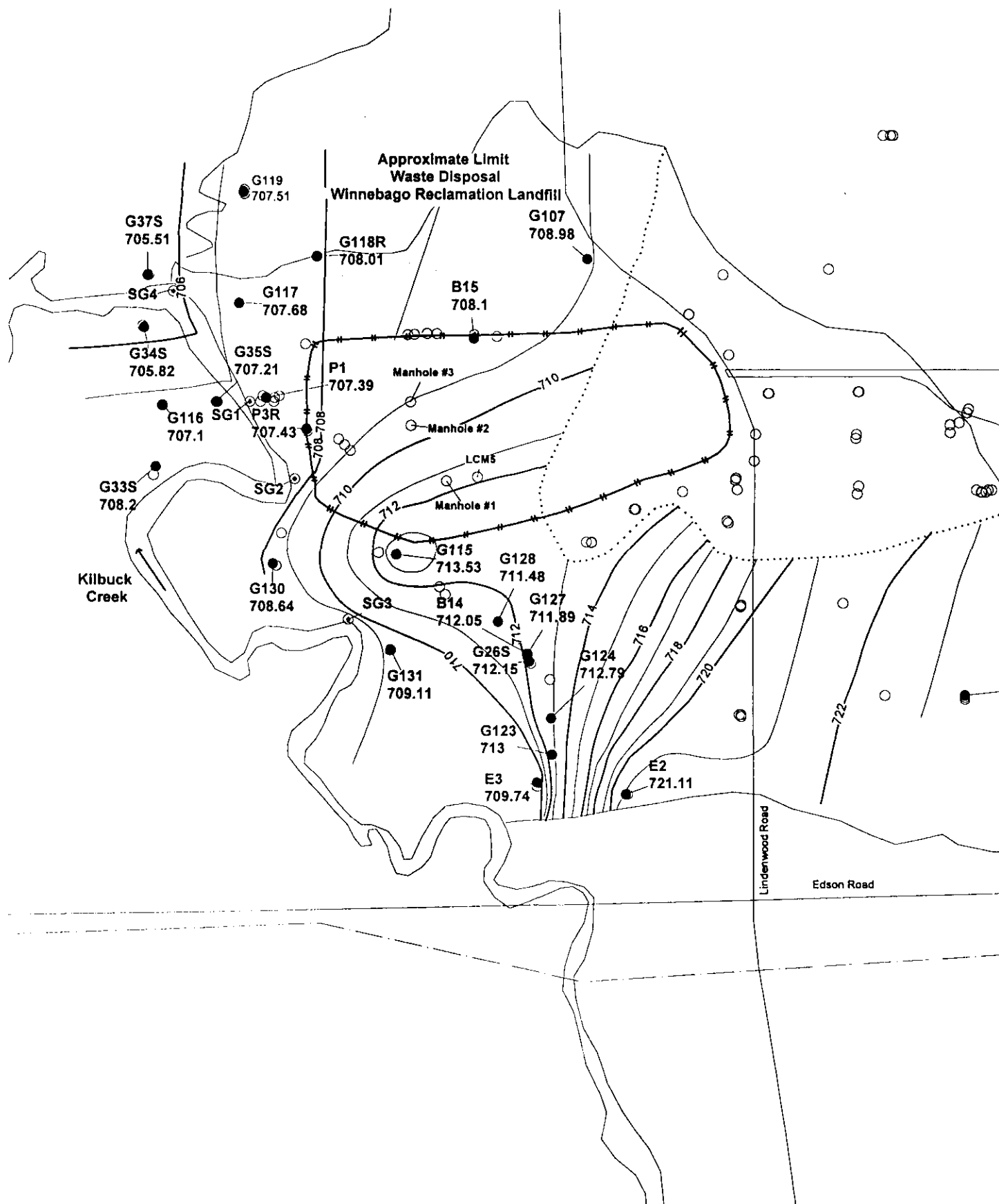
TITLE: Groundwater Elevation Contours
Shallow Zone of Galena-Platteville
Dolomite Aquifer (2/17/95)

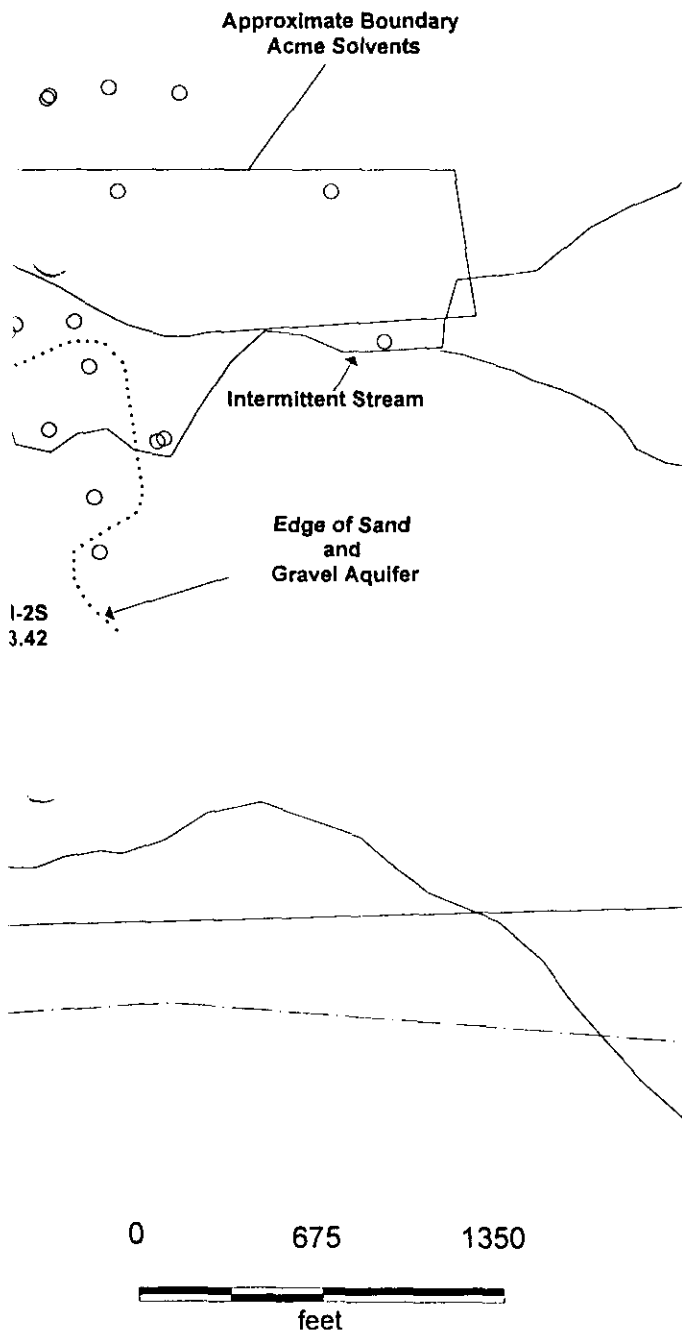
LOCATION: Winnebago Reclamation Services, Rockford, IL.

GeoTrans, inc.

CHECKED:	DB
DRAFTED:	ELA
FILE:	HR_317.WOR
DATE:	9 MAY 1995

FIGURE:
2.18





Winnebago Reclamation Services

LEGEND

- Monitoring Well
- G101 Well I.D. and Groundwater
750.90 Elevation
- ⊙ SG3 Stream Gage I.D.
- 750 Groundwater Elevation Contours
- Intermittent Stream
- - - Edge of Sand and Gravel Aquifer

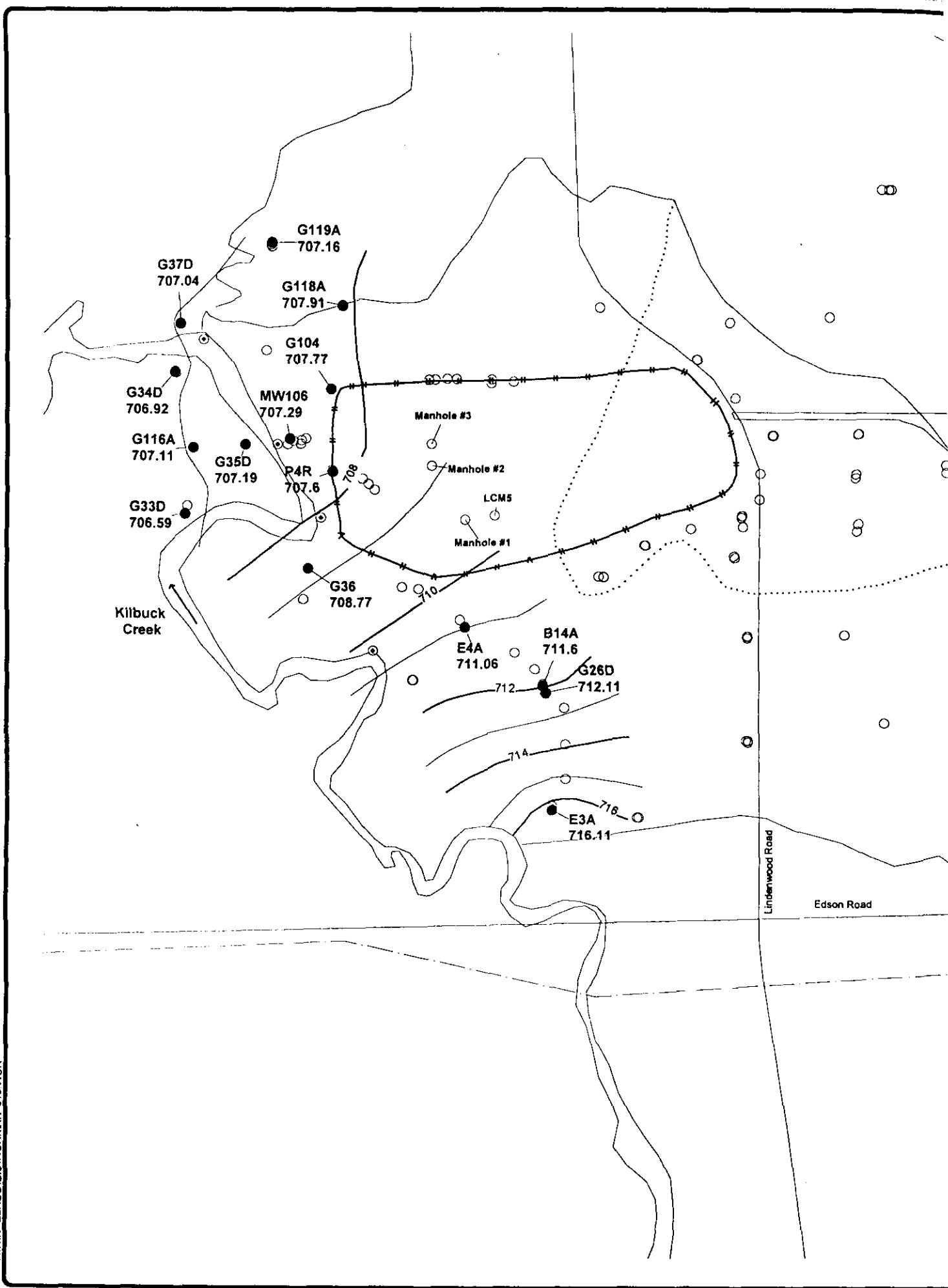
TITLE: Groundwater Elevation Contours
Upper Zone of the Sand and Gravel Aquifer
(4/25/95)

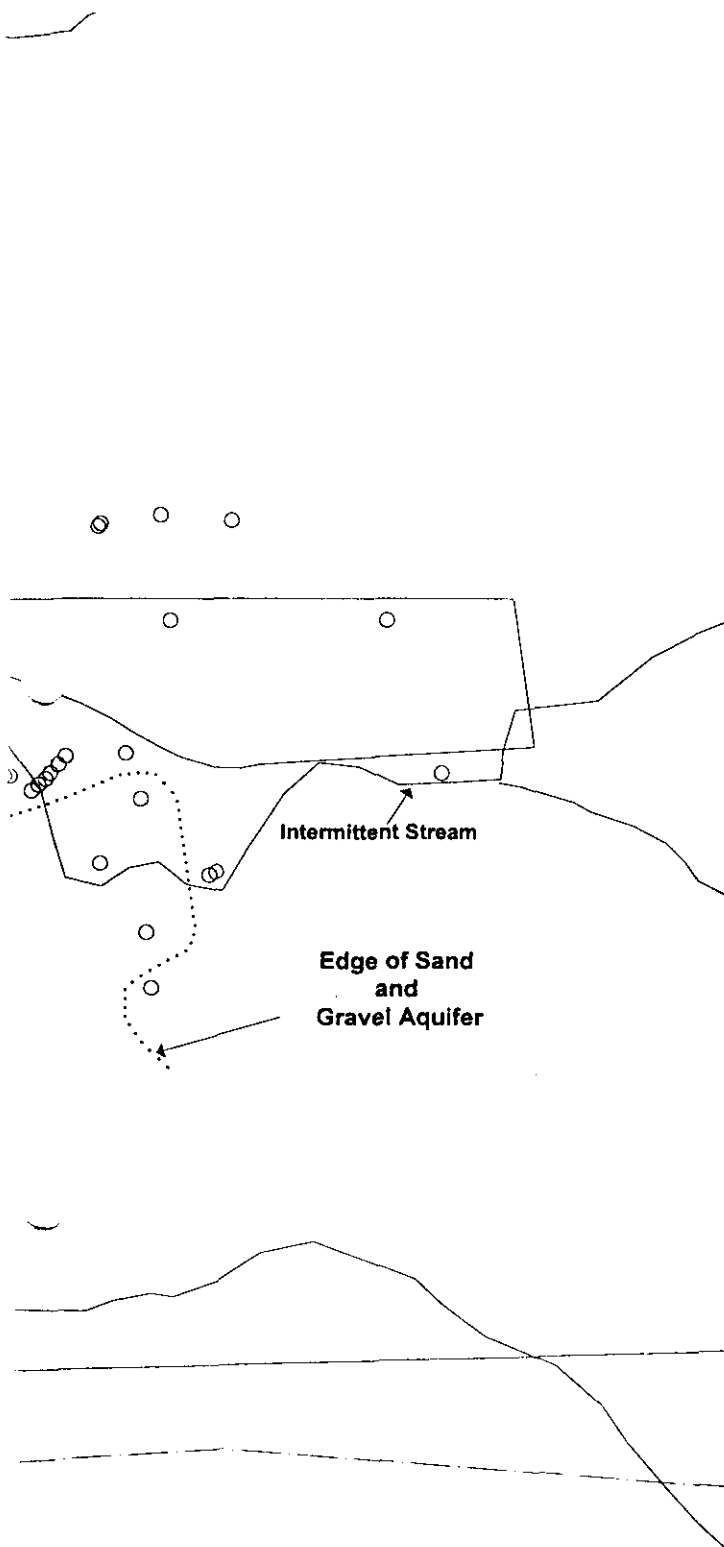
LOCATION:
Winnebago Reclamation Services, Rockford, IL.

GeoTrans, inc.

CHECKED:	DB
DRAFTED:	ELA
FILE:	HR_318.WOR
DATE:	9 MAY 1995

FIGURE:
2.19





0 675 1350

feet



Winnebago Reclamation Services

LEGEND

○ Monitoring Well

● G101 Well I.D. and Groundwater
750.90 Elevation

⊙ SG3 Stream Gage I.D.

~~~~~ 750 Groundwater Elevation Contours

~~~~~ Intermittent Stream

~~~~~ Edge of Sand and Gravel Aquifer

TITLE: Groundwater Elevation Contours  
Lower Zone of the Sand and Gravel Aquifer  
(4/25/95)

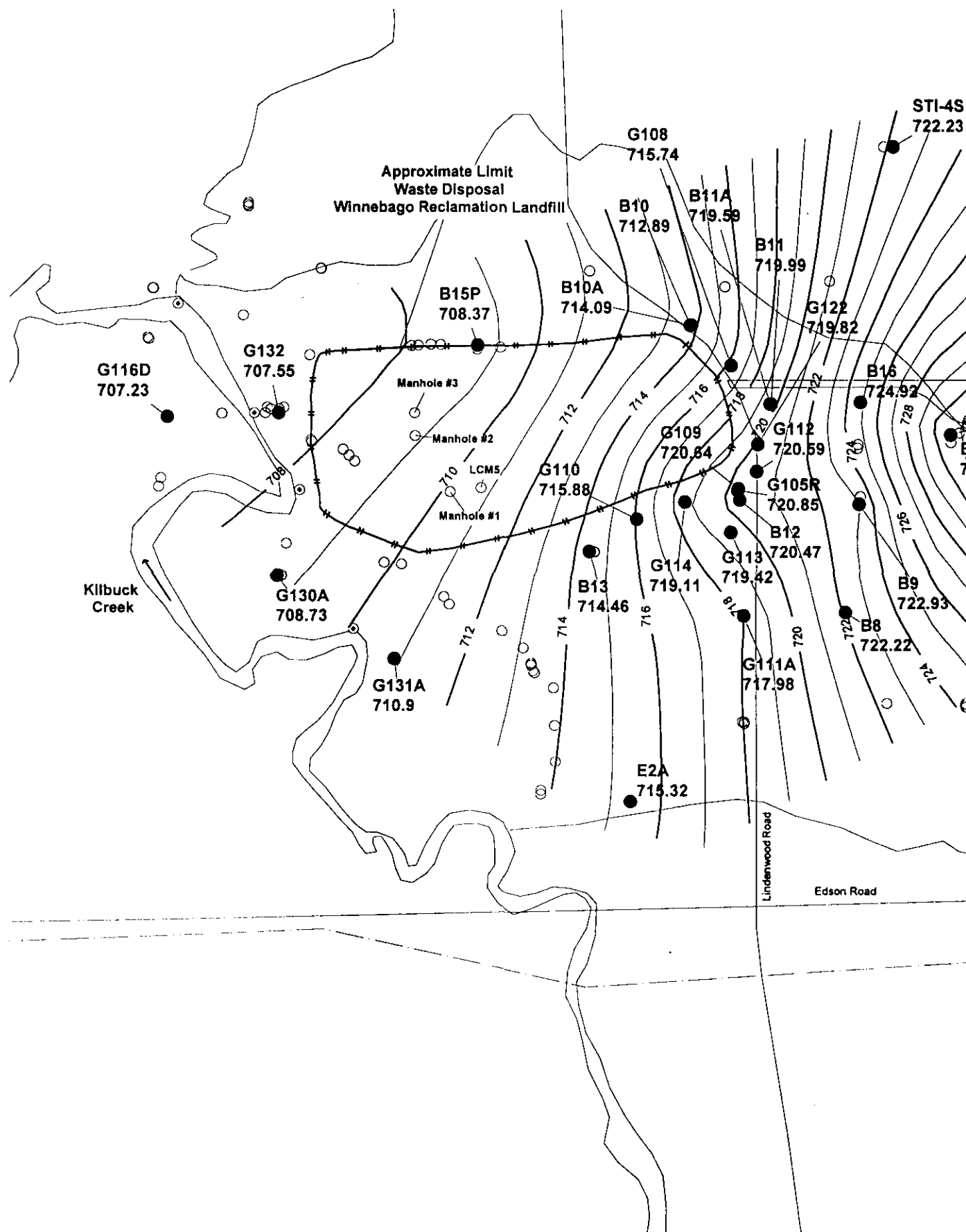
LOCATION: Winnebago Reclamation Services, Rockford, IL.

**GeoTrans, inc.**

|          |            |
|----------|------------|
| CHECKED: | DB         |
| DRAFTED: | ELA        |
| FILE:    | HR_319.WOR |
| DATE:    | 9 MAY 1995 |

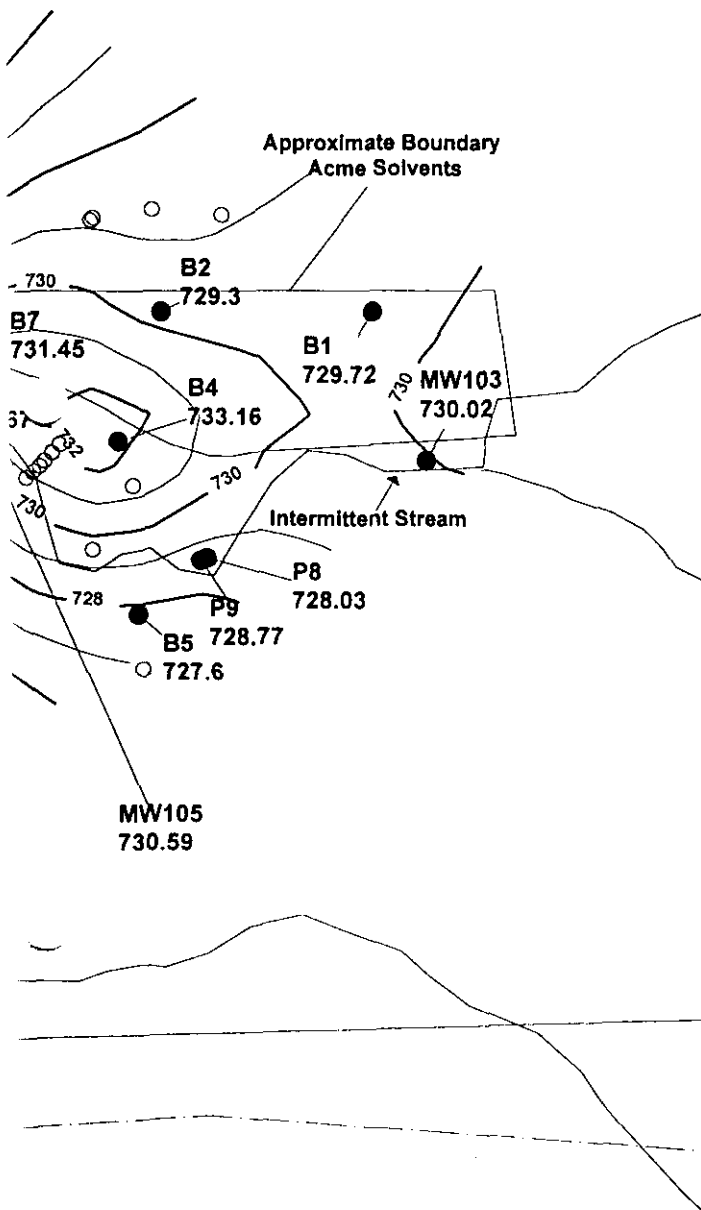
FIGURE:  
2.20











0 675 1350  
feet



## Winnebago Reclamation Services

### LEGEND

- Monitoring Well
- G101 Well I.D. and Groundwater  
750.90 Elevation
- ⊙ SG3 Stream Gage I.D.
- 750 Groundwater Elevation Contours
- Intermittent Stream
- Edge of Sand and Gravel Aquifer

TITLE: Groundwater Elevation Contours  
Shallow Zone of Galena-Platteville  
Dolomite Aquifer (4/25/95)

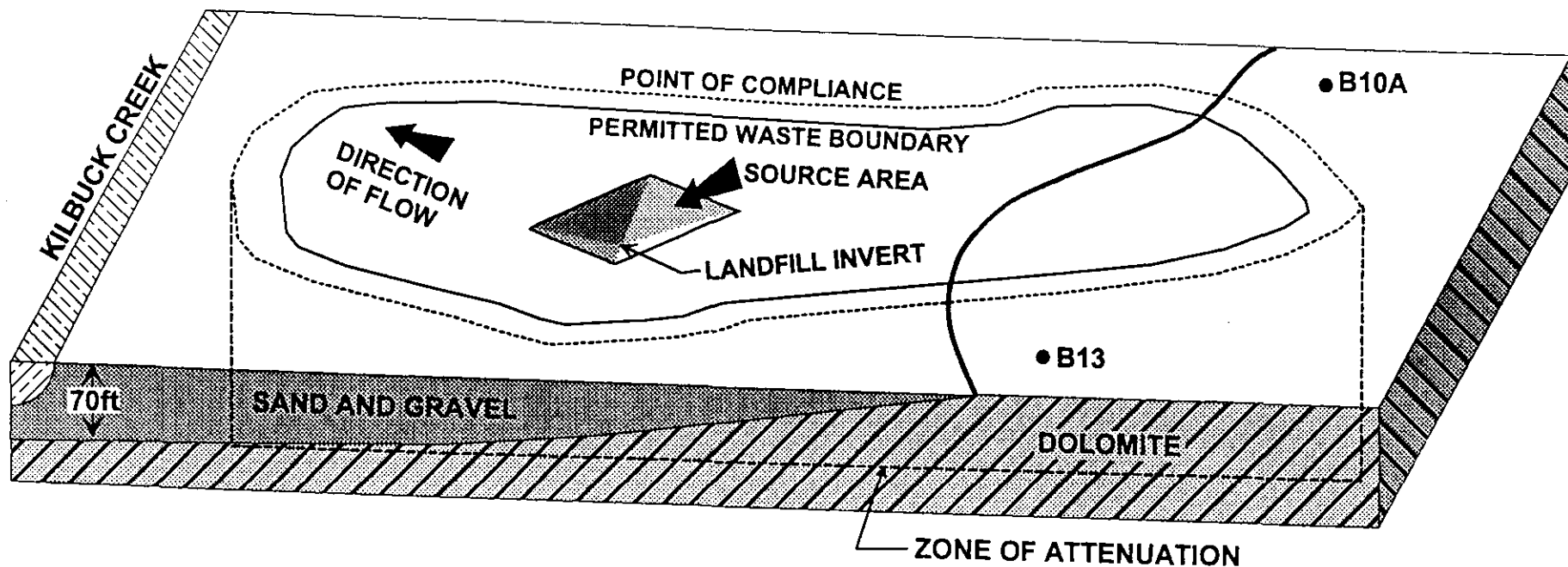
LOCATION: Winnebago Reclamation Services, Rockford, IL.

**GeoTrans, inc.**

|          |            |
|----------|------------|
| CHECKED: | DB         |
| DRAFTED: | ELA        |
| FILE:    | HR_320.WOR |
| DATE:    | 9 MAY 1995 |


FIGURE:  
2.21





HORIZONTAL AND VERTICAL DIMENSIONS NOT TO SCALE

|                                                  |         |              |        |
|--------------------------------------------------|---------|--------------|--------|
| TITLE                                            |         |              |        |
| CONCEPTUAL MODEL                                 |         |              |        |
| LOCATION                                         |         |              |        |
| Winnebago Reclamation Services, Rockford, IL.    |         |              |        |
| <b>GeoTrans, inc.</b><br>GROUNDWATER SPECIALISTS | CHECKED | D.B.         | FIGURE |
|                                                  | DRAFTED | P.K.         |        |
|                                                  | FILE    | 7735002A.DS4 |        |
|                                                  | DATE    | 8-28-95      |        |
|                                                  |         |              | 2.22   |

|                                                                                                                                           |         |                                                            |                                                                          |
|-------------------------------------------------------------------------------------------------------------------------------------------|---------|------------------------------------------------------------|--------------------------------------------------------------------------|
| TITLE                                                                                                                                     |         | SIMPLIFICATION OF CONCEPTUAL MODEL FOR MATHEMATICAL MODEL. |                                                                          |
| LOCATION                                                                                                                                  |         | Winnebago Reclamation Services, Rockford, IL.              |                                                                          |
| <br><b>GeoTrans, inc.</b><br>GROUNDWATER SPECIALISTS | CHECKED | D.S.                                                       | FIGURE<br><br><div style="font-size: 2em; font-weight: bold;">2.23</div> |
|                                                                                                                                           | DRAWN   | P.K.                                                       |                                                                          |
|                                                                                                                                           | FILE    | 7735002A.DS4                                               |                                                                          |
|                                                                                                                                           | DATE    | 6-26-95                                                    |                                                                          |

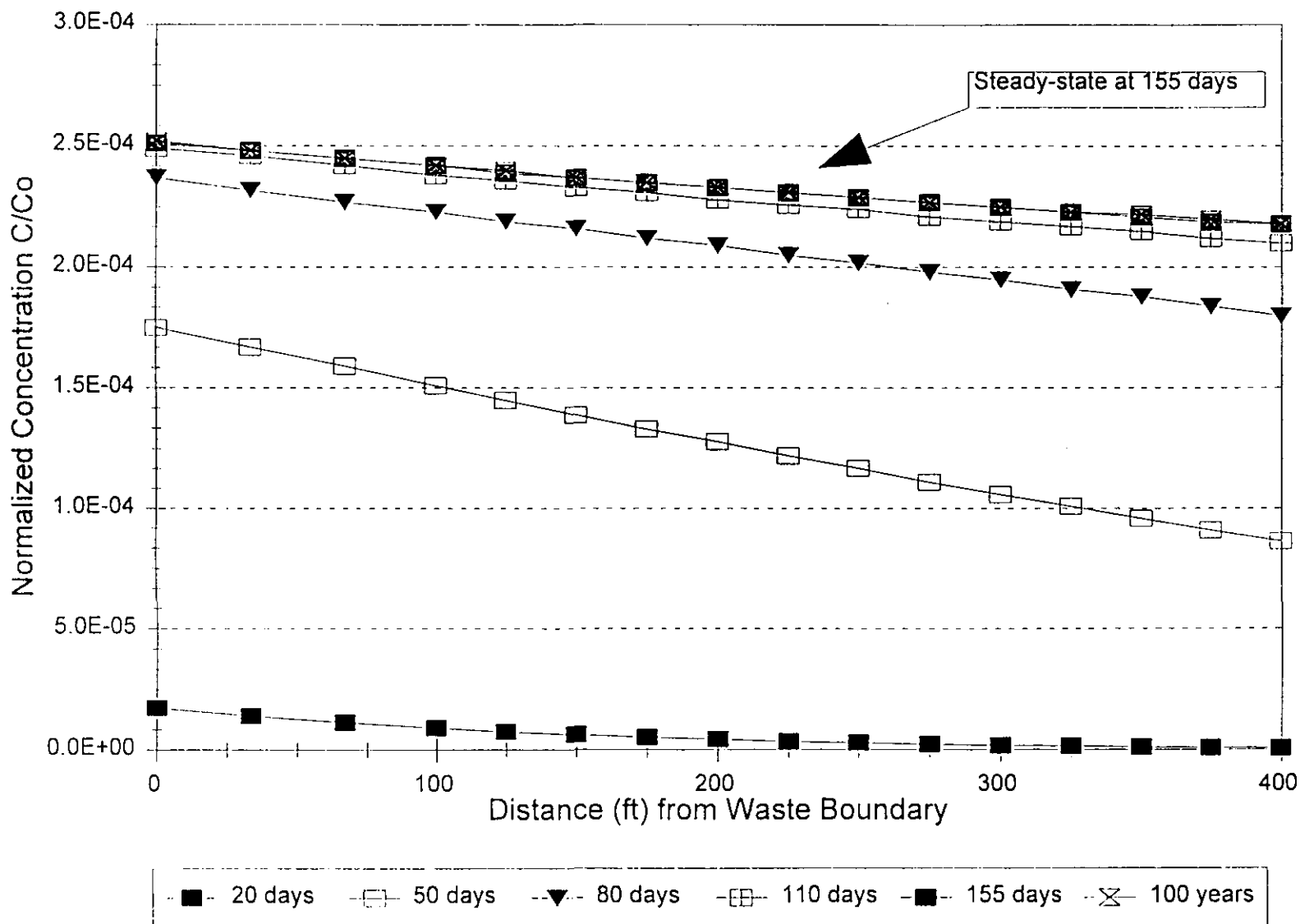


Figure 3.1. Normalized concentrations versus distance through time for the baseline model (Run 80).

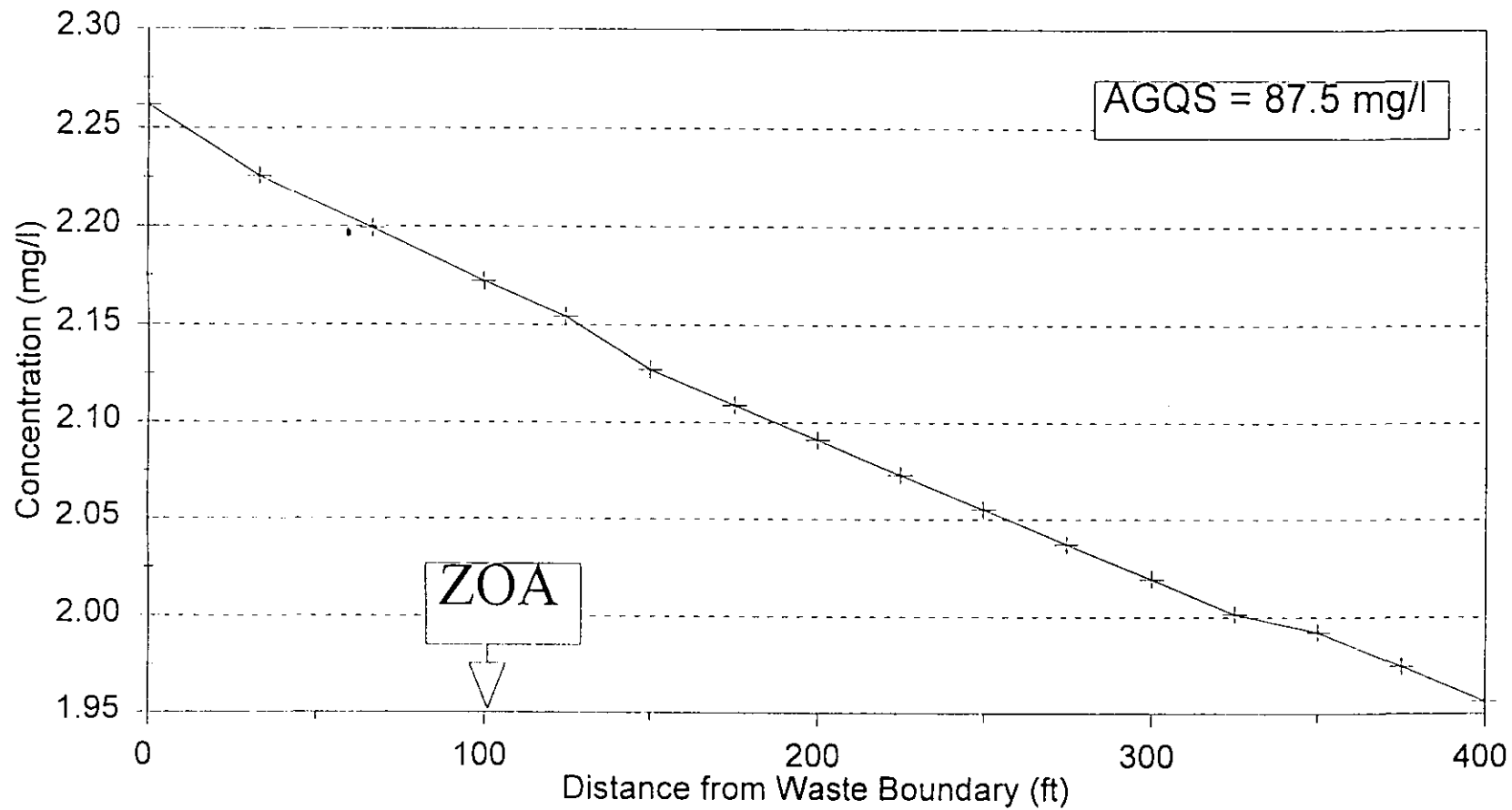


Figure 3.2. Chloride surrogate concentration versus distance from the edge of the waste boundary at 100 years.

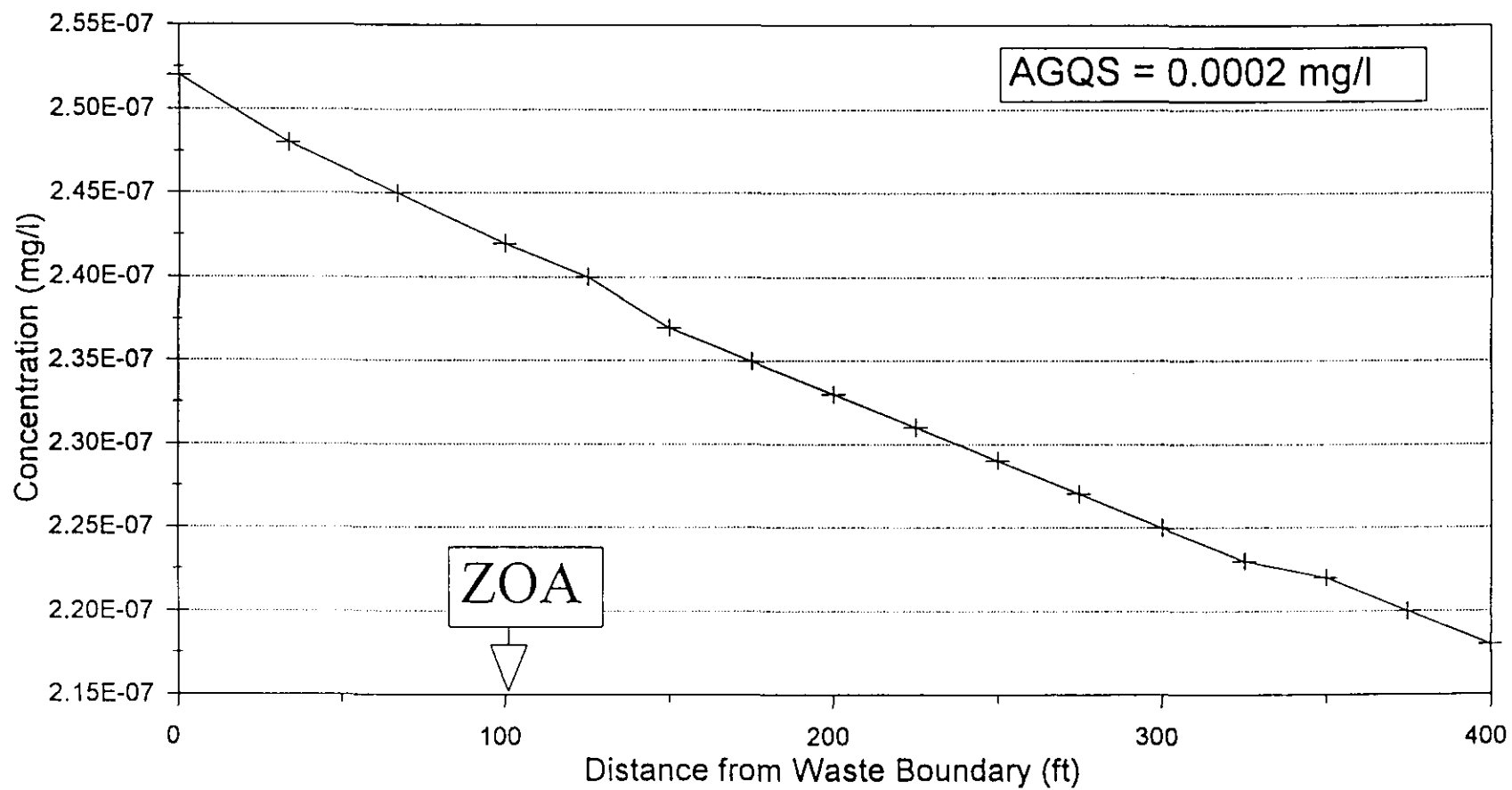


Figure 3.3. Mercury concentrations versus distance from the edge of the waste boundary at 100 years.

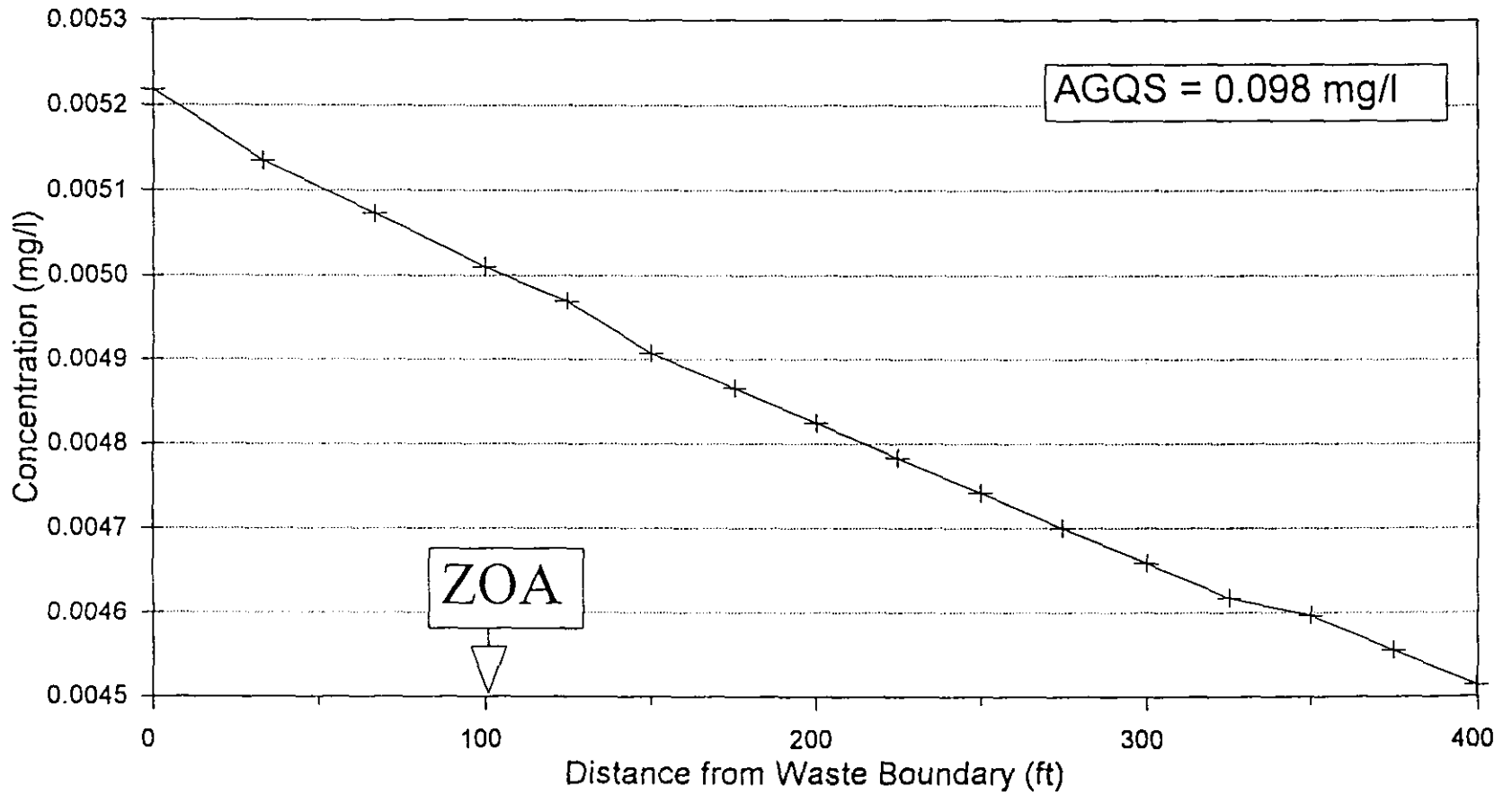


Figure 3.4. Boron surrogate concentrations versus distance from the edge of the waste boundary at 100 years.



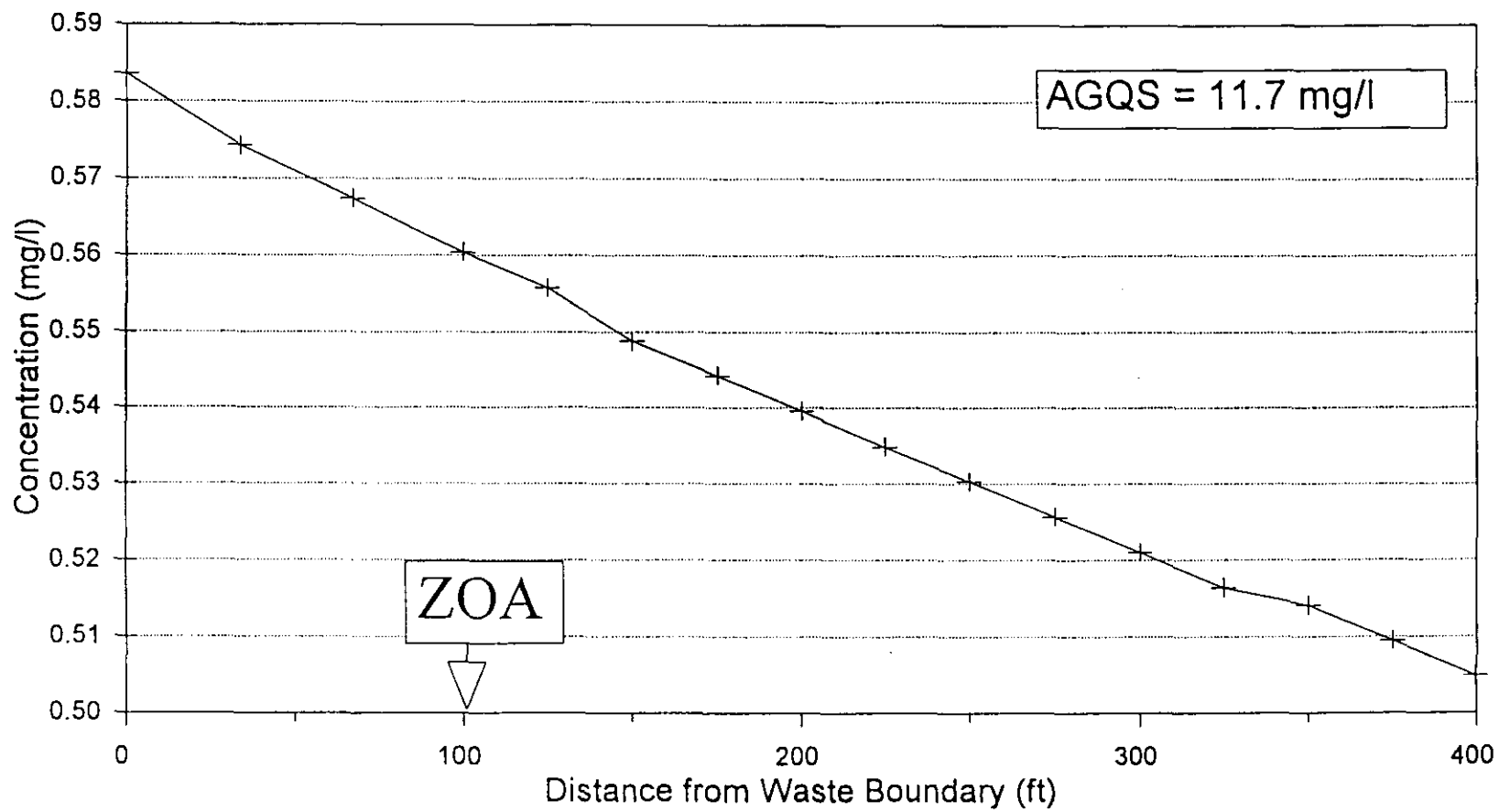


Figure 3.5. Nitrate-nitrite surrogate concentrations versus distance from the edge of the waste boundary at 100 years.

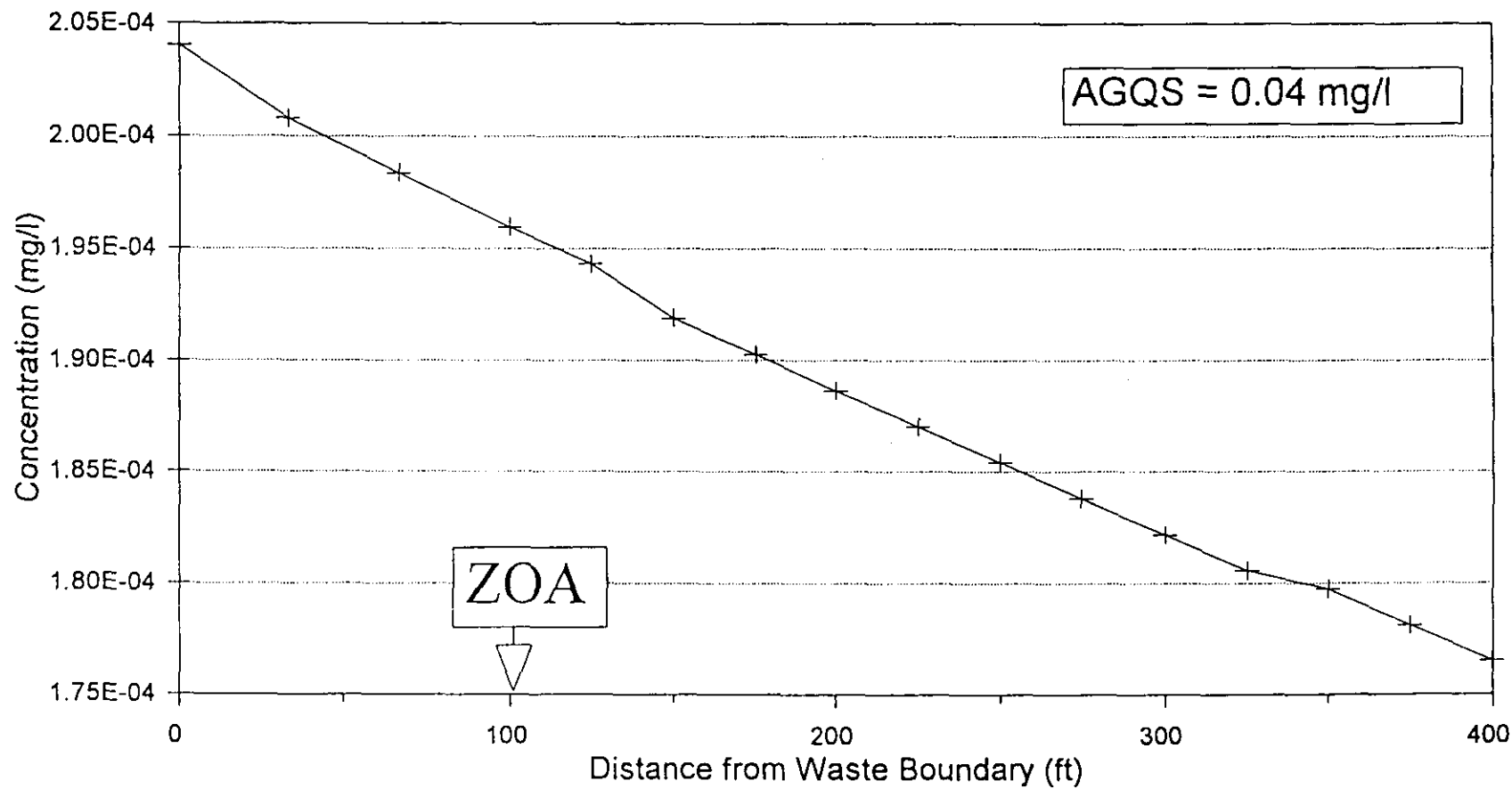


Figure 3.6. Nickel surrogate concentrations versus distance from the edge of the waste boundary at 100 years.

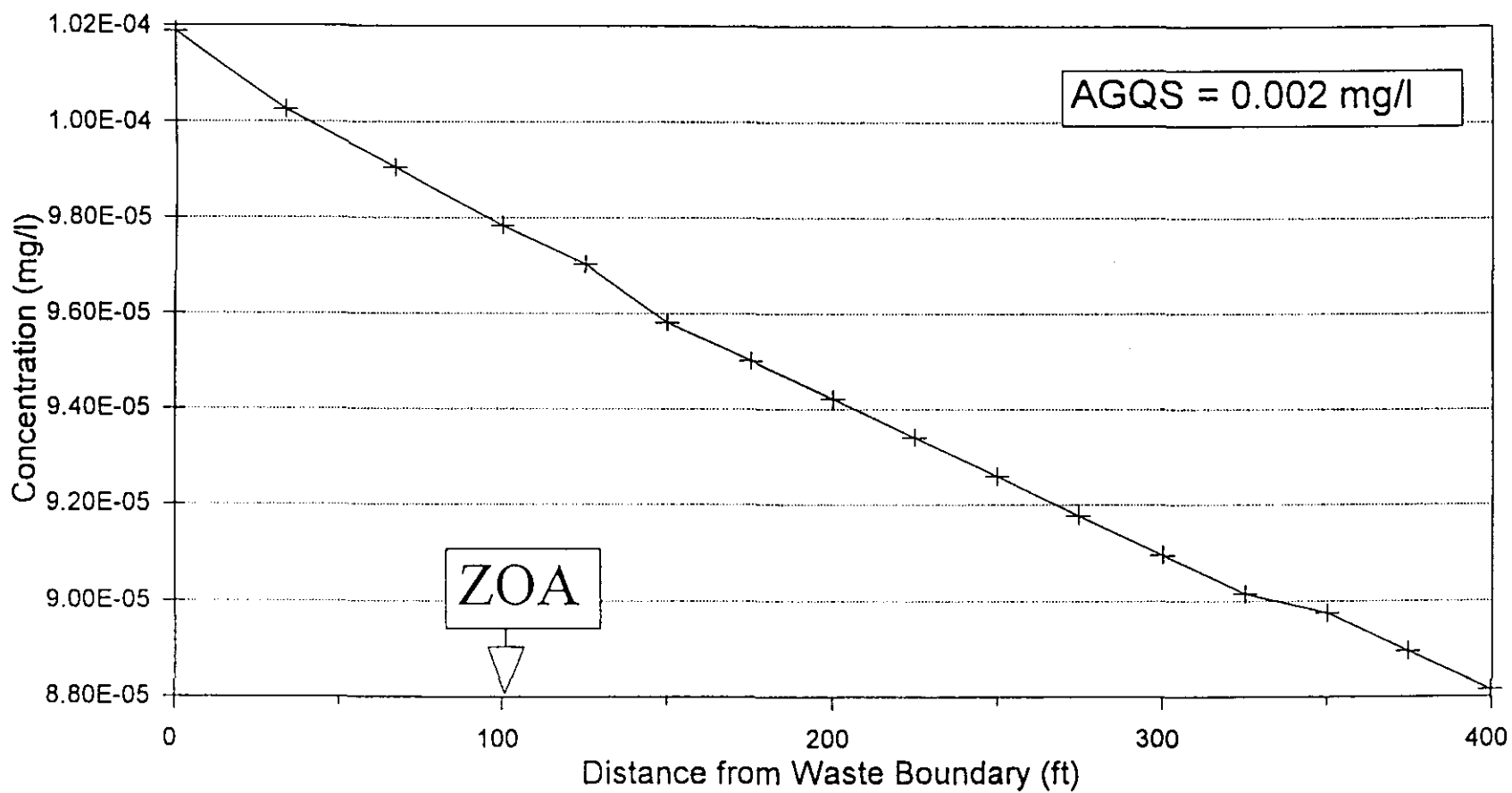


Figure 3.7. Selenium surrogate concentrations versus distance from the edge of the waste boundary at 100 years.

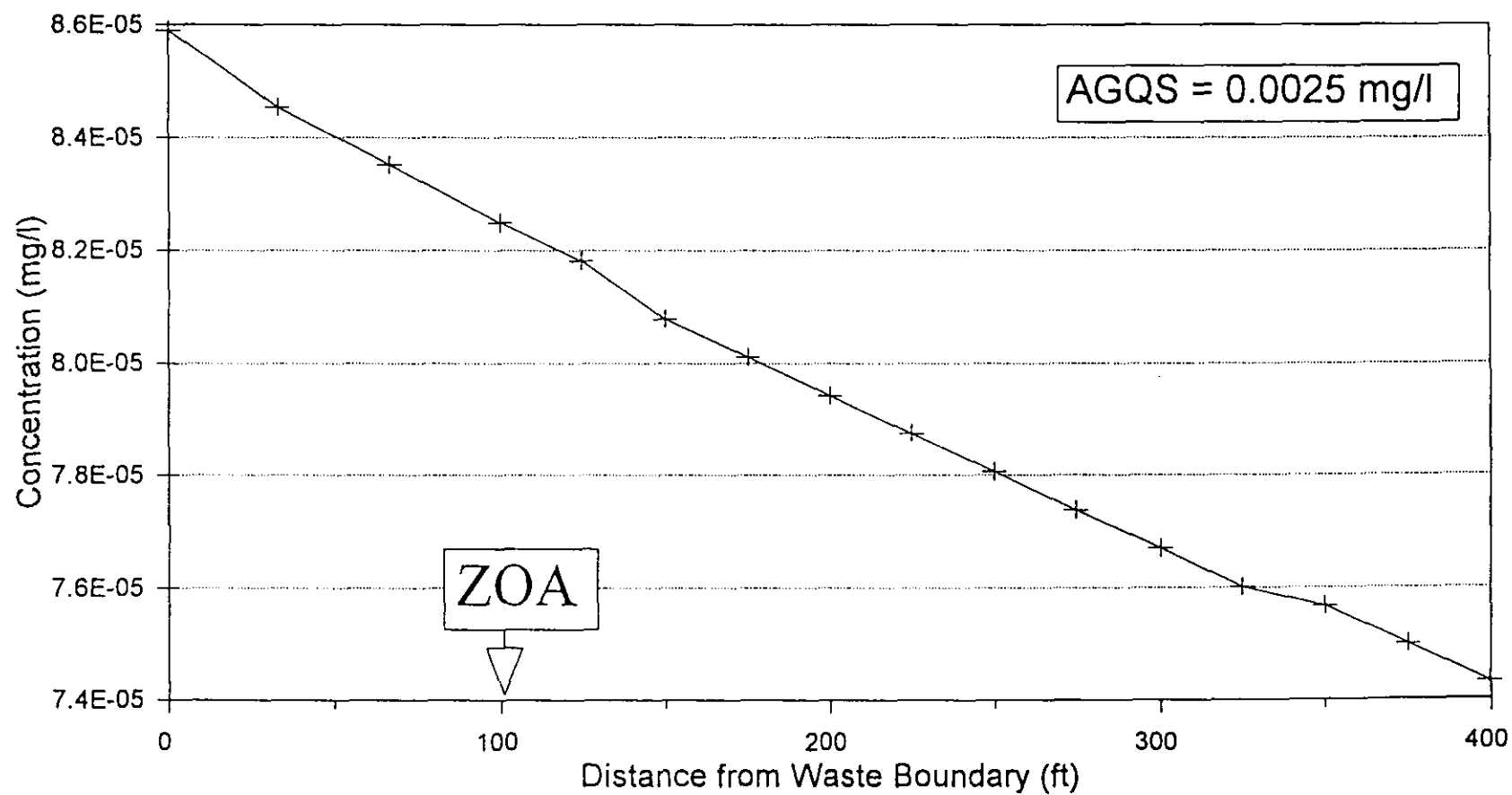


Figure 3.8. Organic surrogate concentrations versus distance from the edge of the waste boundary at 100 years.

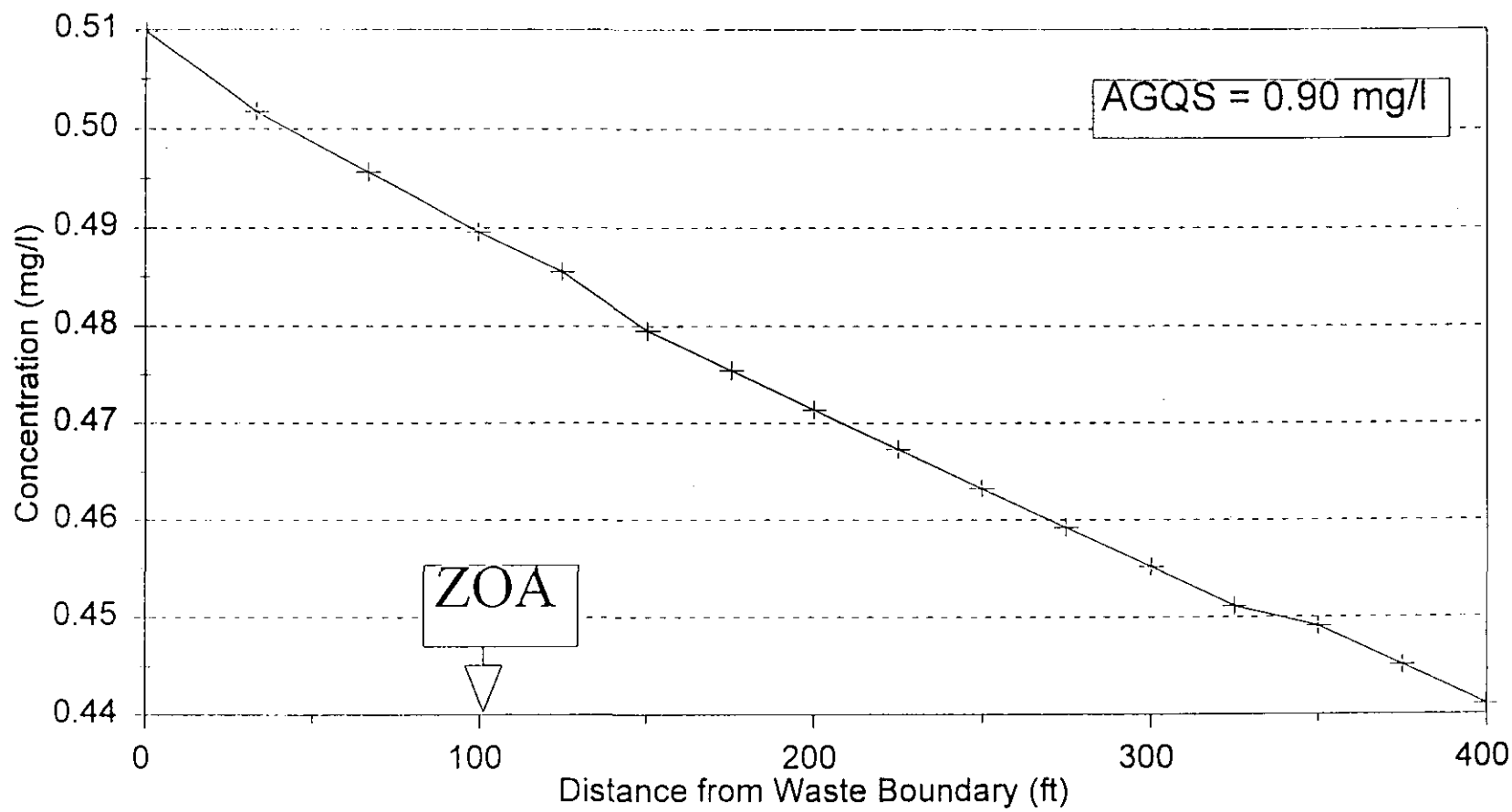


Figure 3.9. Ammonia surrogate concentrations versus distance from the edge of the waste boundary at 100 years.

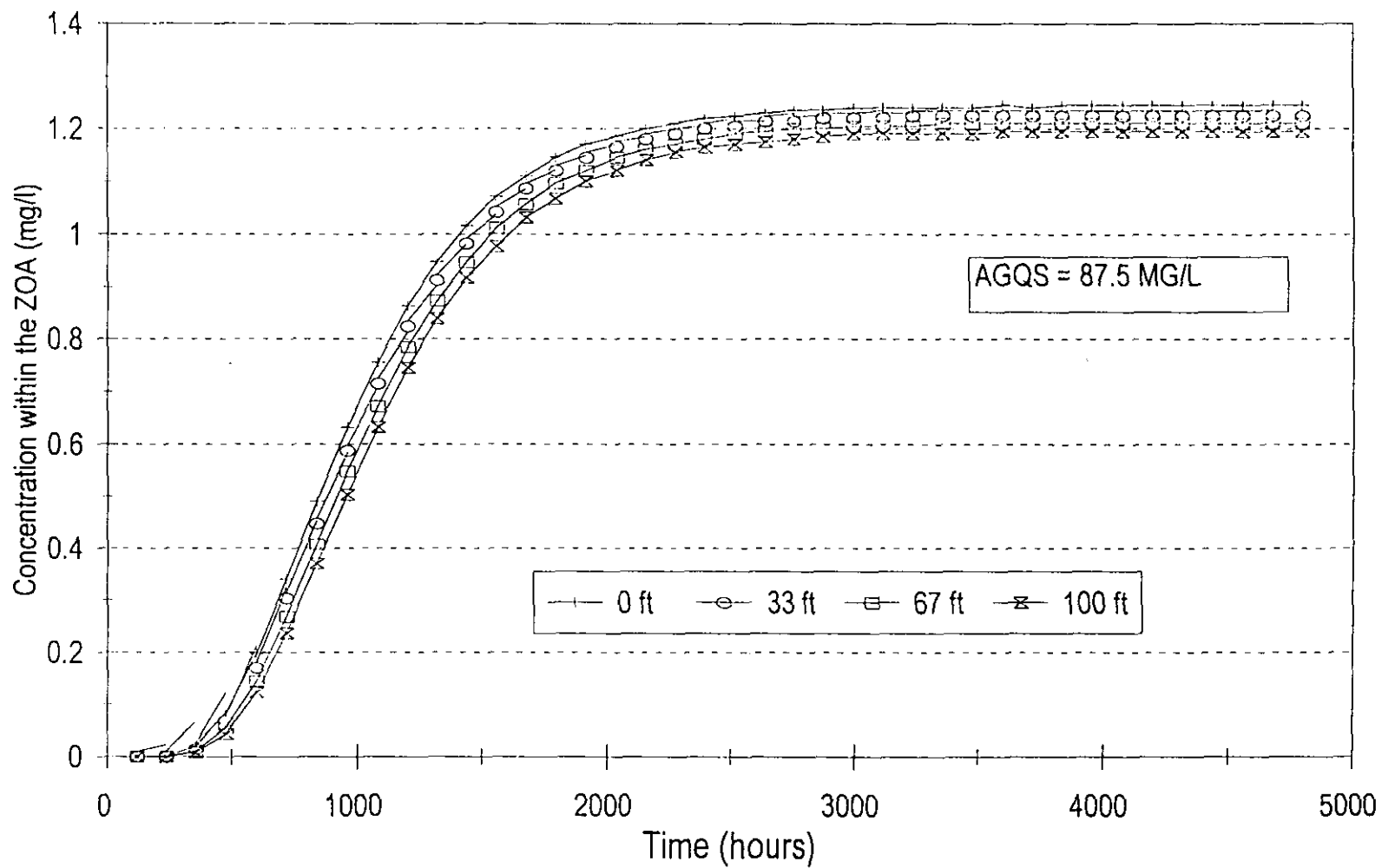


Figure 3.10. Chloride surrogate concentrations versus time within the ZOA.

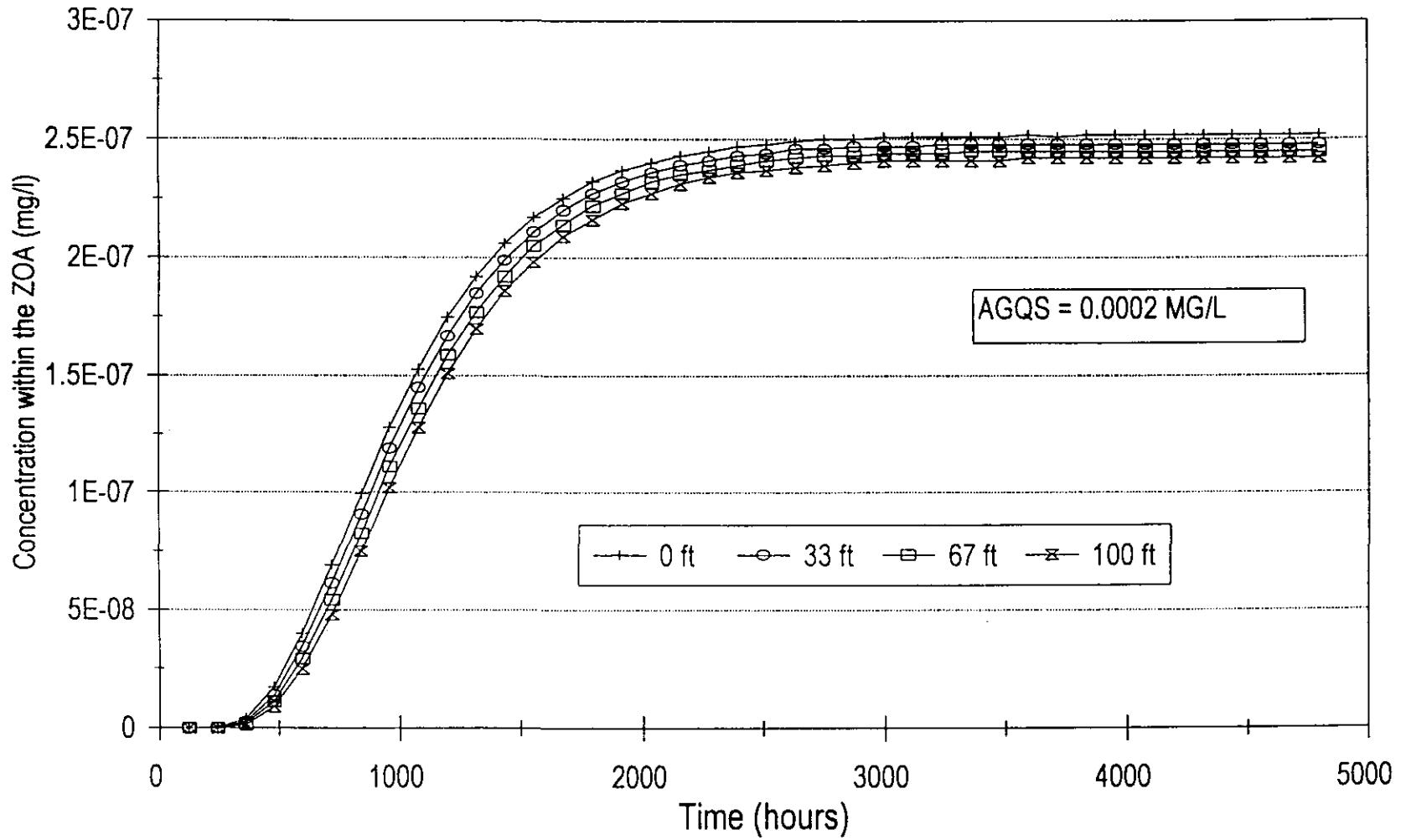


Figure 3.11. Mercury surrogate concentrations versus time within the ZOA.

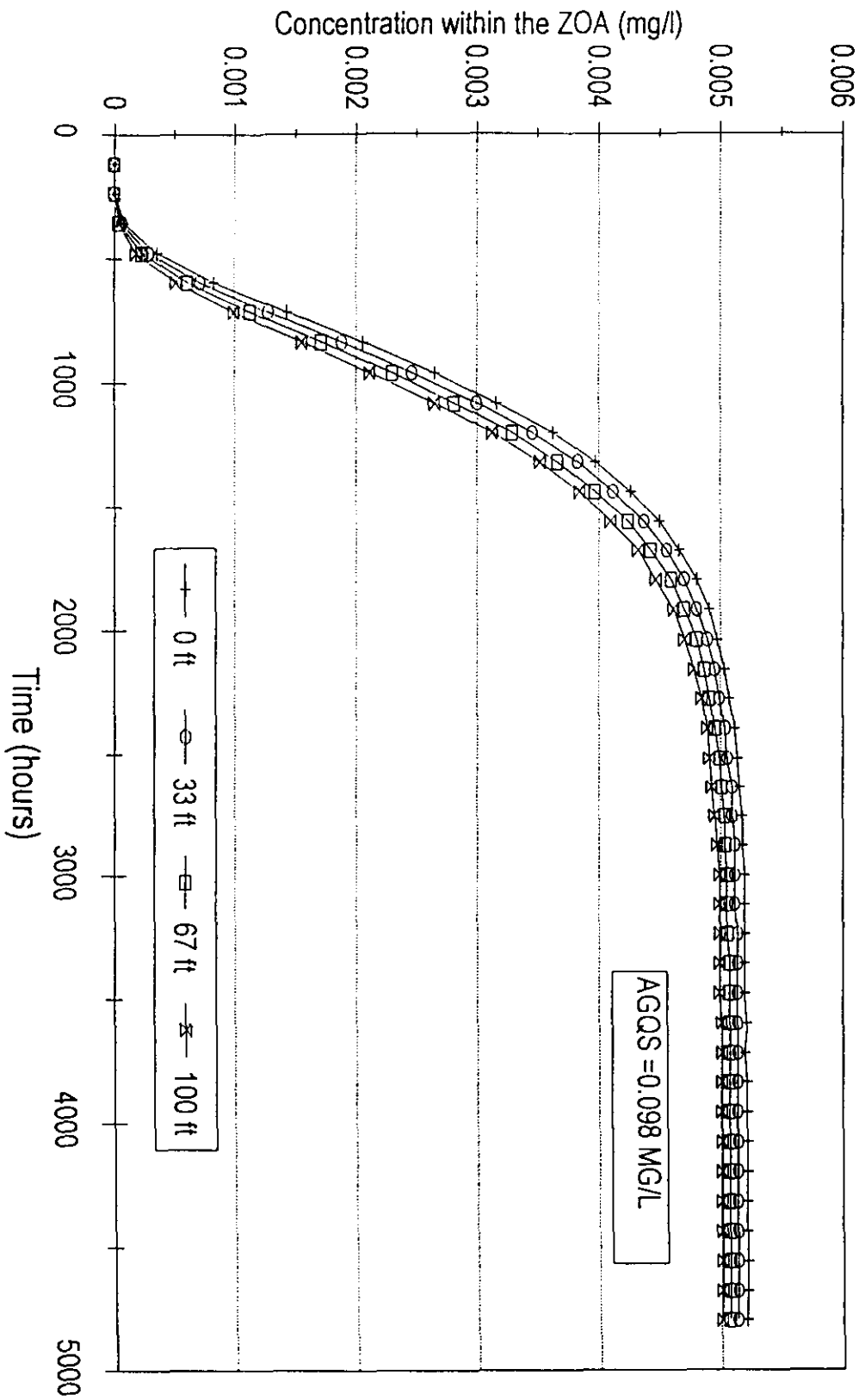


Figure 3.12. Boron surrogate concentrations versus time within the ZOA.



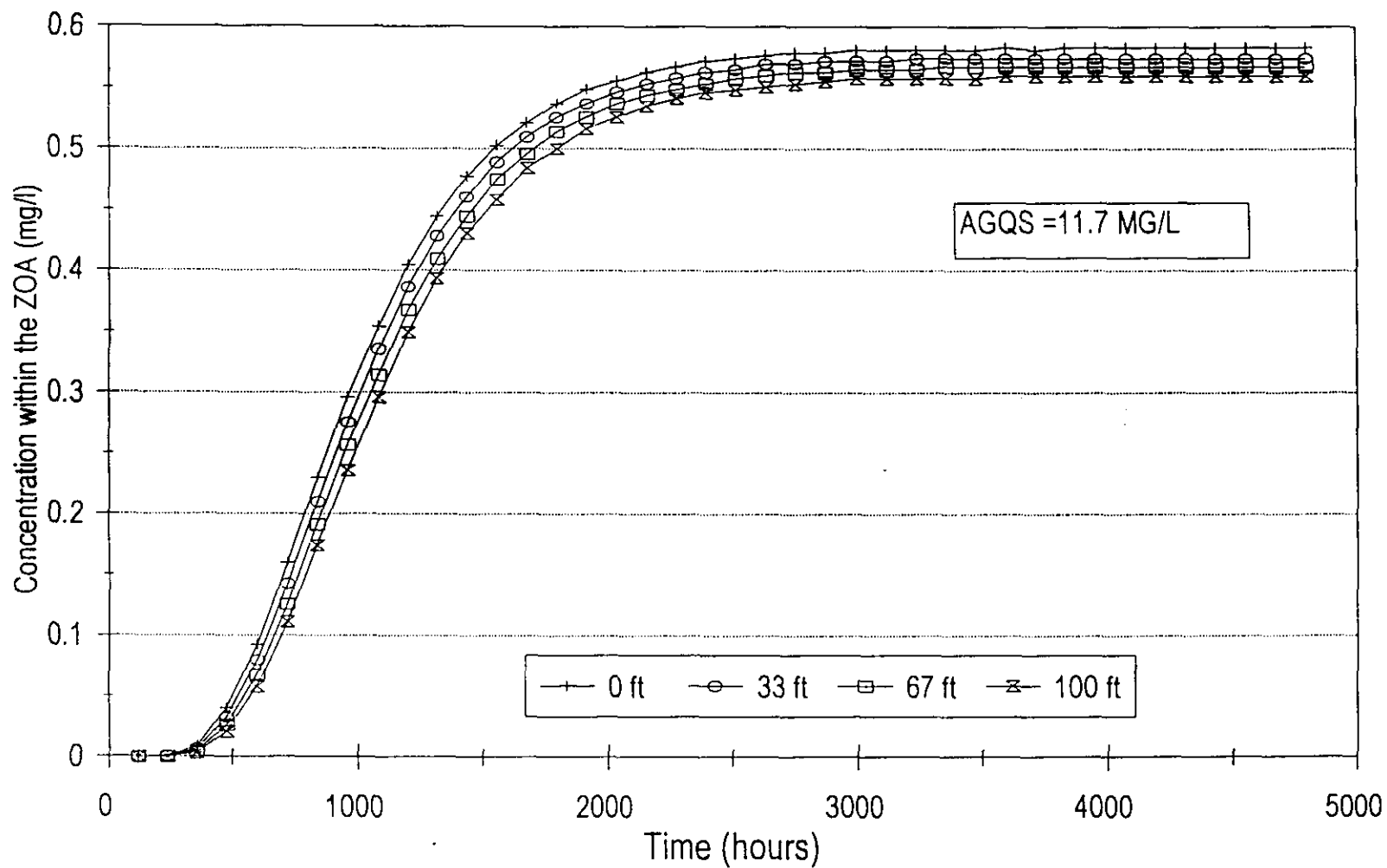


Figure 3.13. Nitrate-nitrite surrogate concentrations versus time within the ZOA.

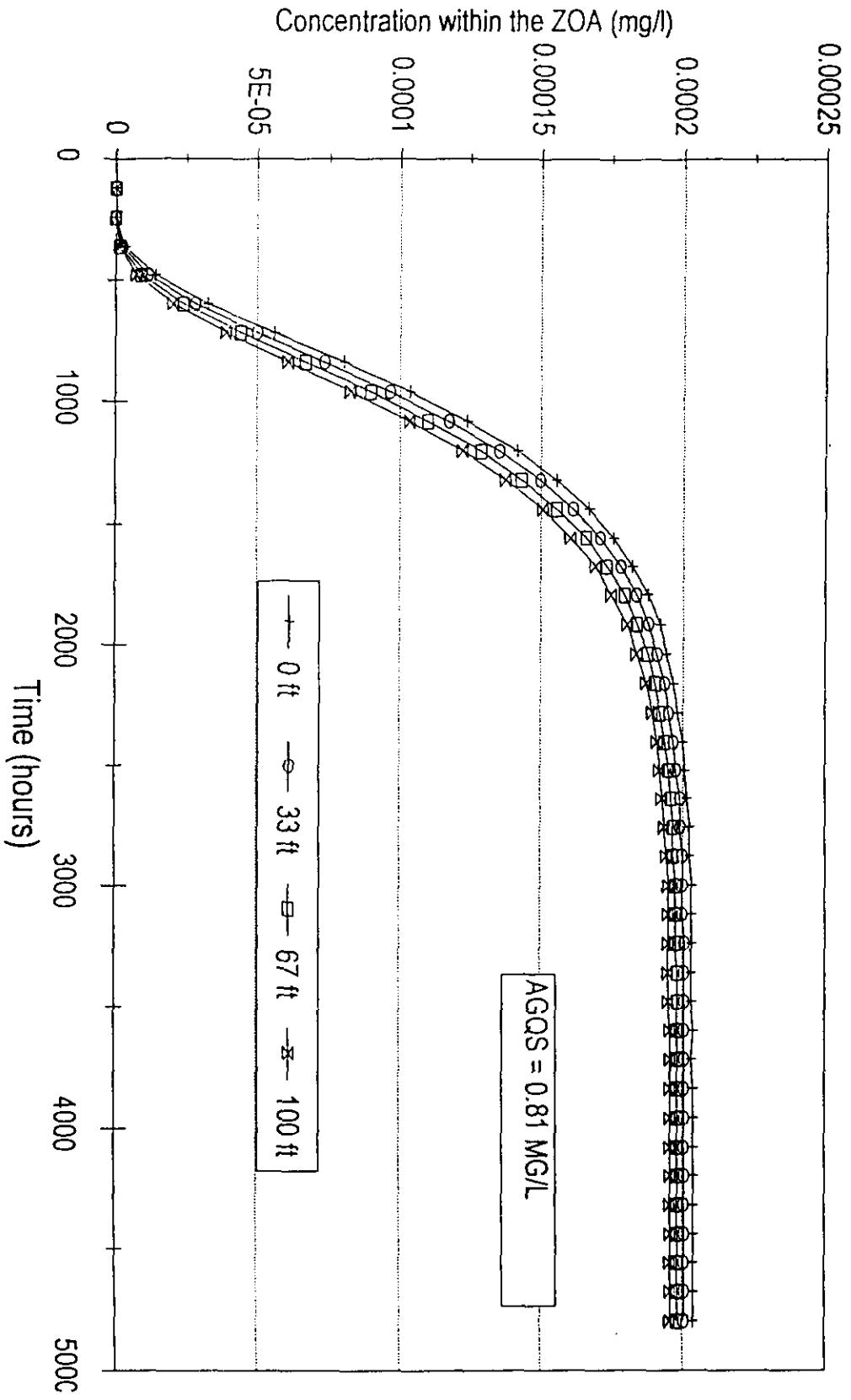


Figure 3.14. Nickel surrogate concentrations versus time within the ZOA.

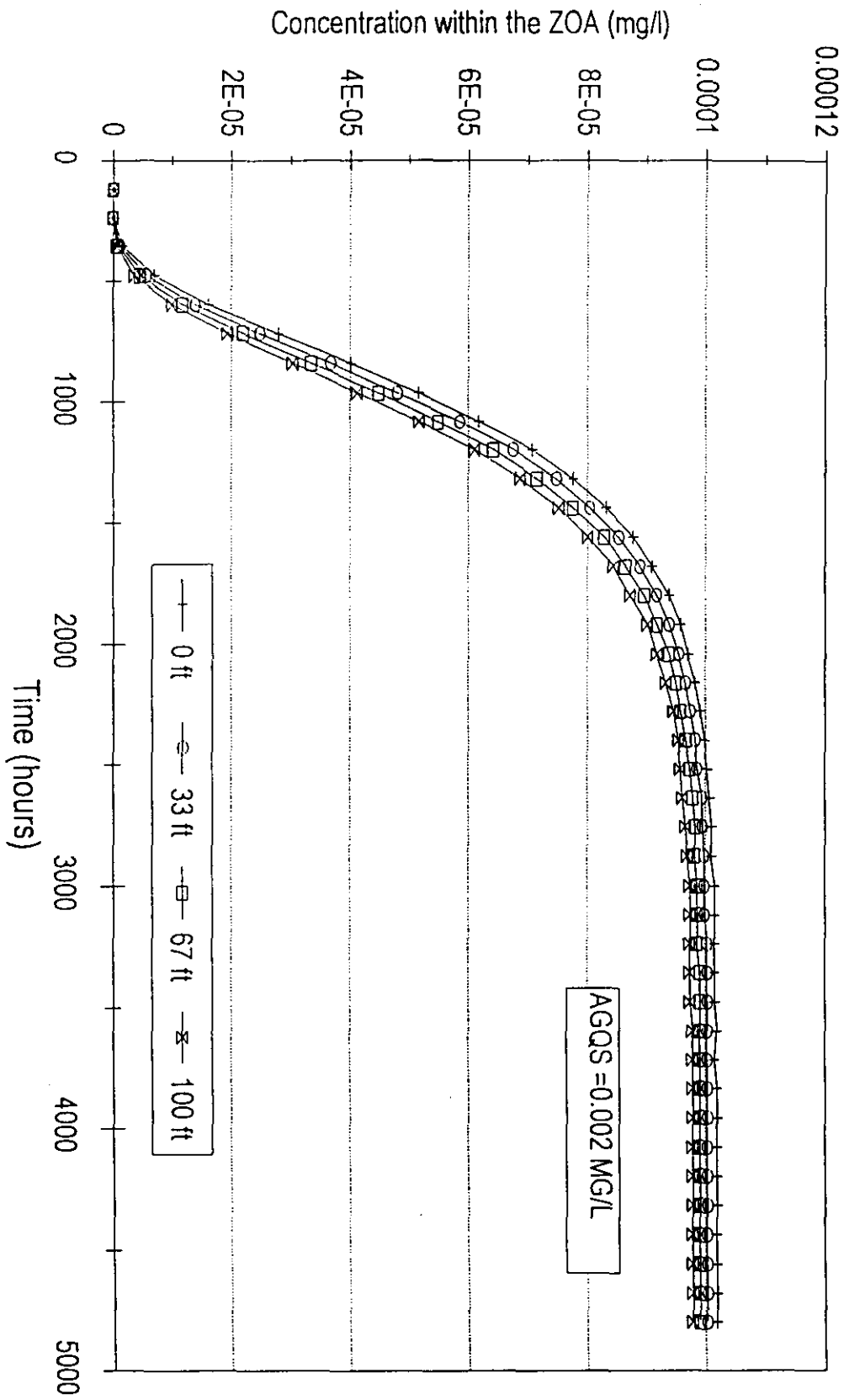


Figure 3.15. Selenium surrogate concentrations versus time within the ZOA.

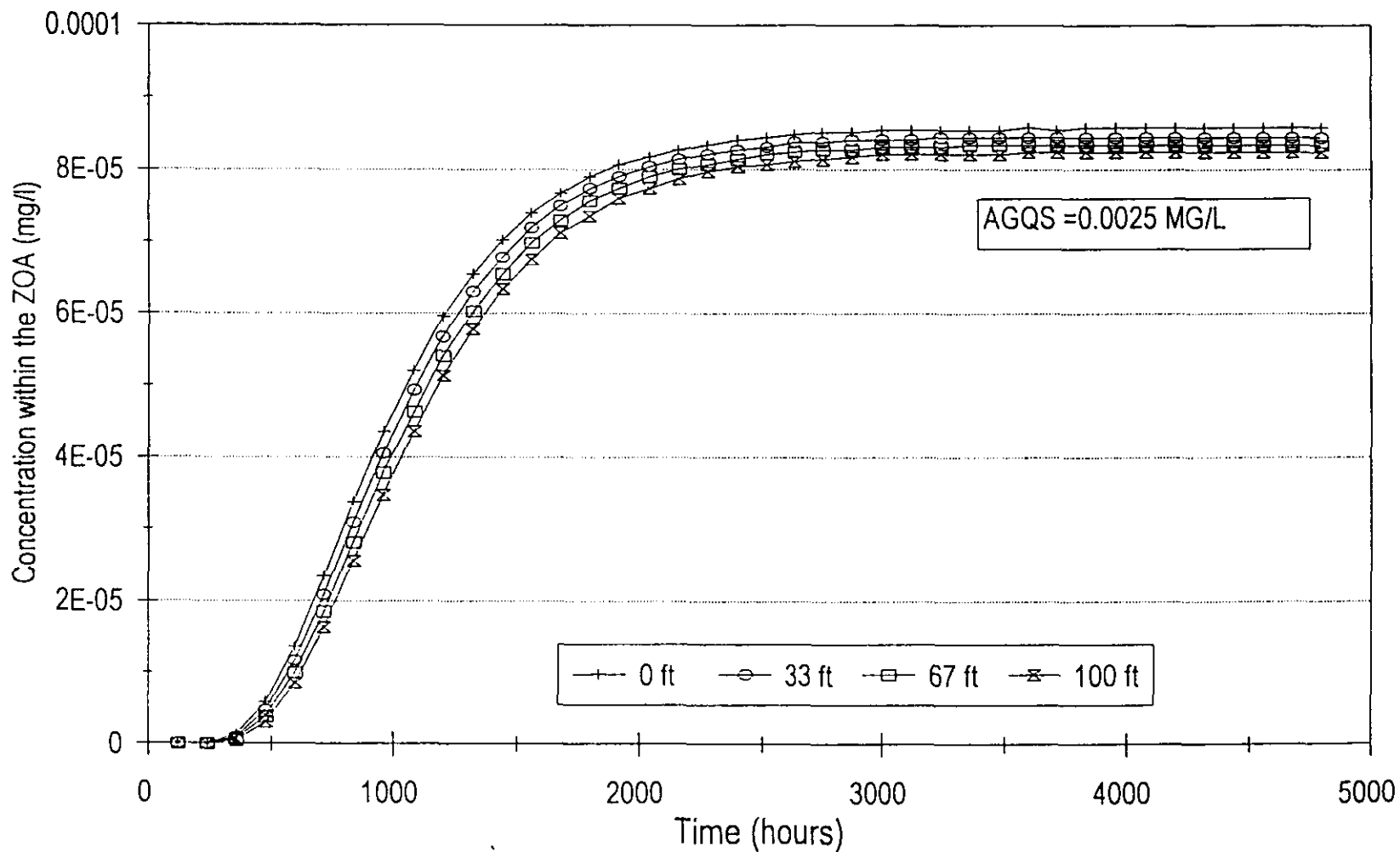


Figure 3.16. Organic surrogate concentrations versus time within the ZOA.

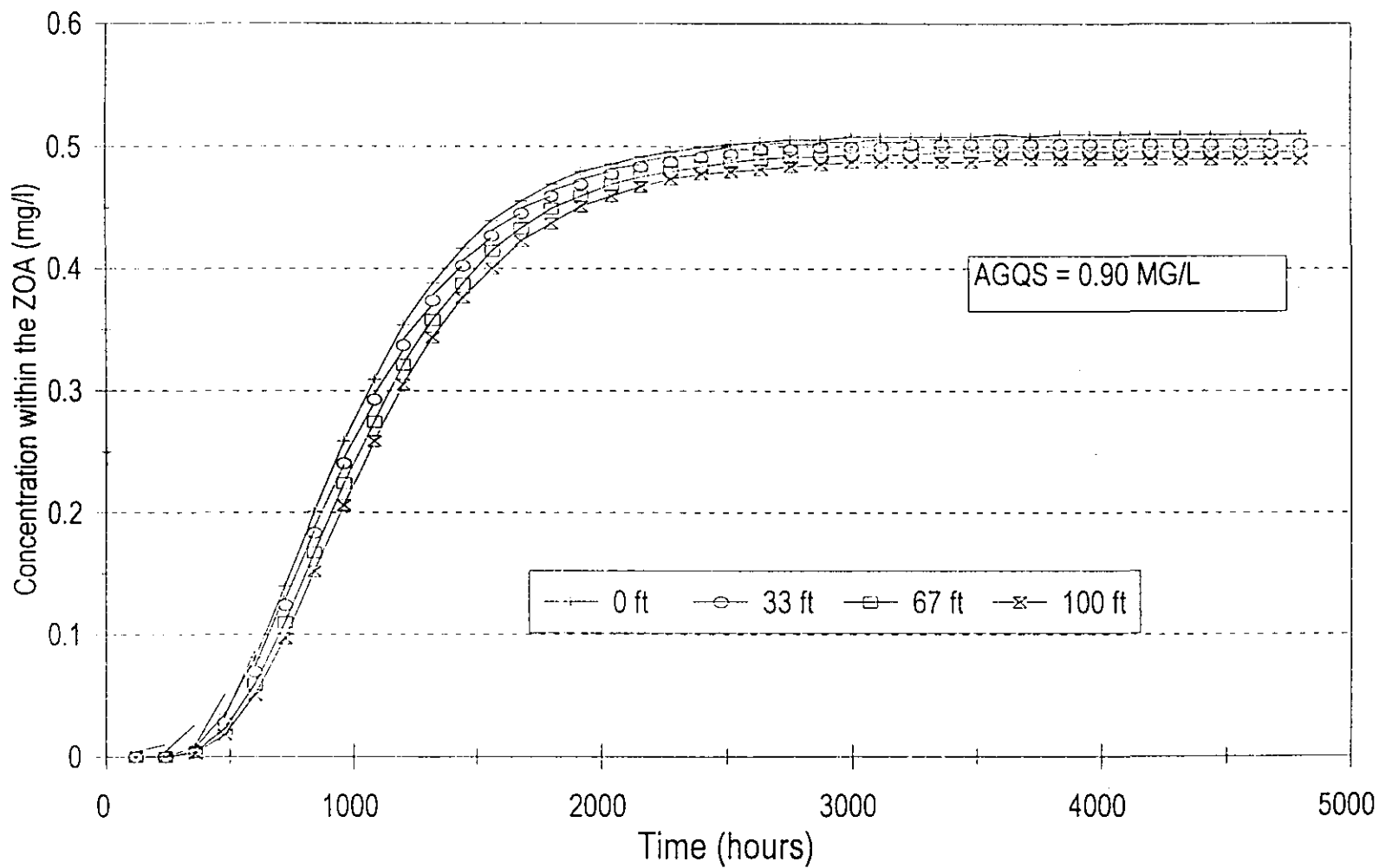


Figure 3.17. Ammonia concentration versus time within the ZOA.

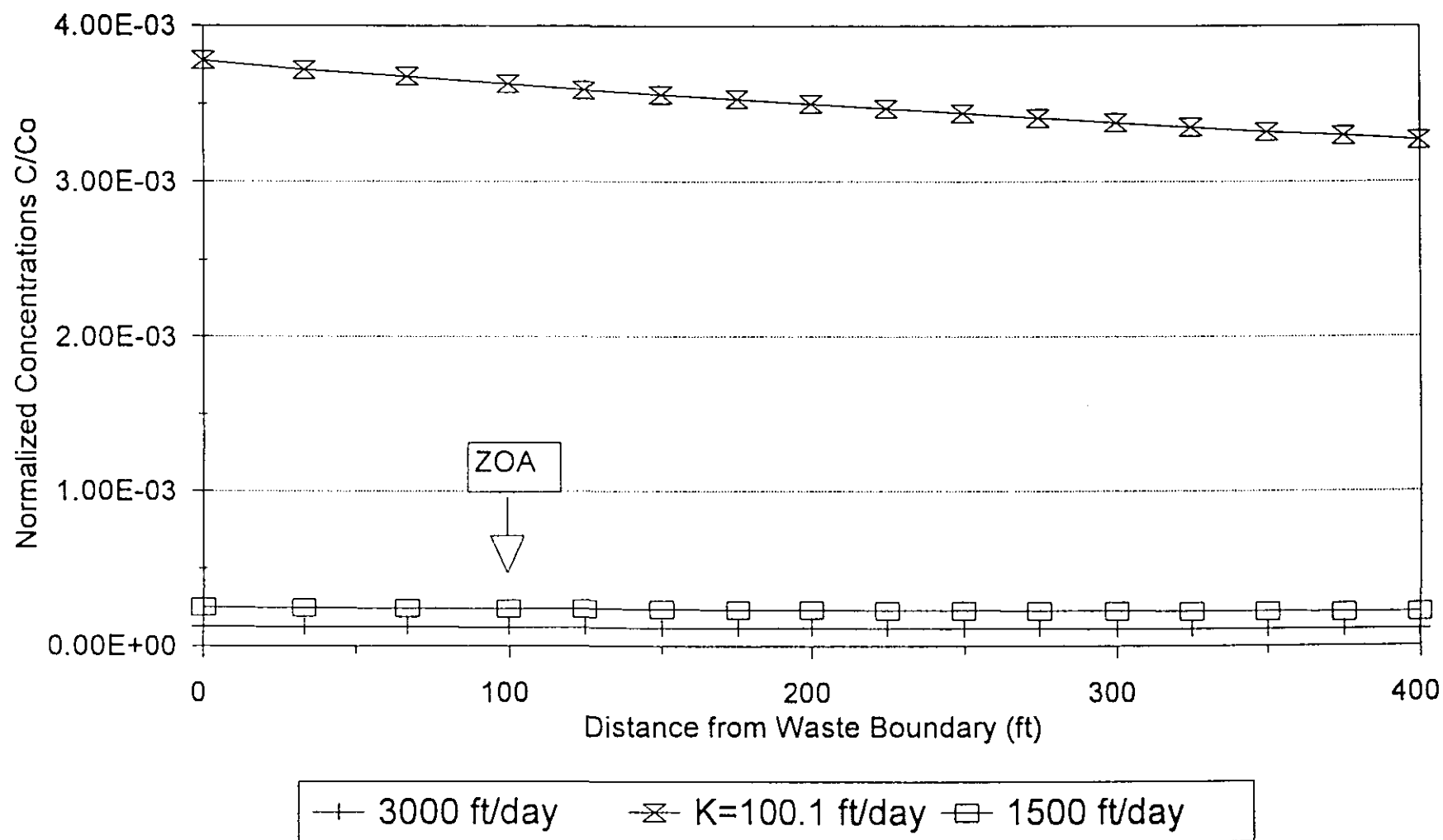
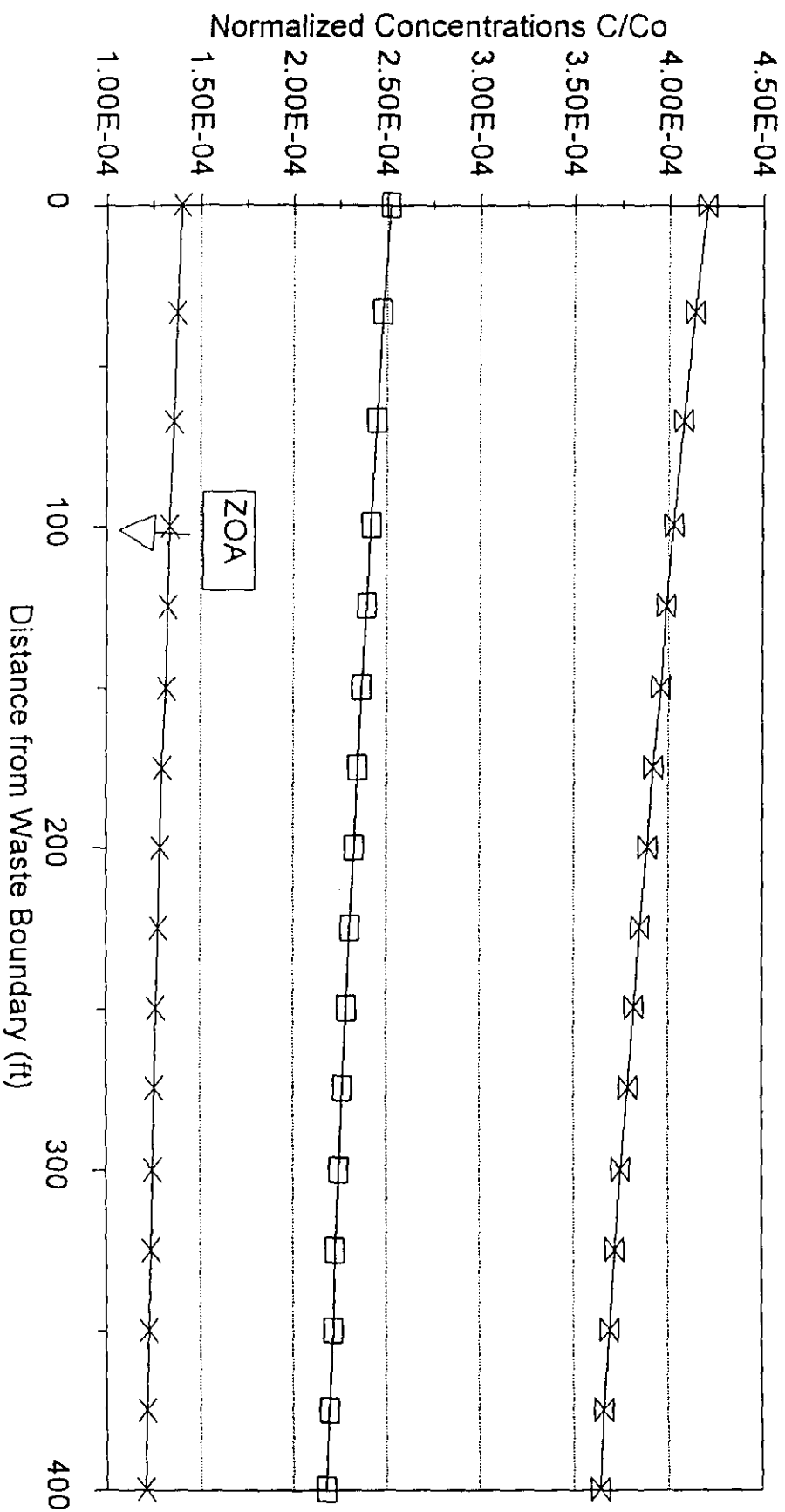


Figure 3.18. Concentration versus distance at 100 years as a function of hydraulic conductivity.



\* .009    □ .005    x .003

Figure 3.19. Concentration versus distance at 100 years as a function of hydraulic gradient.

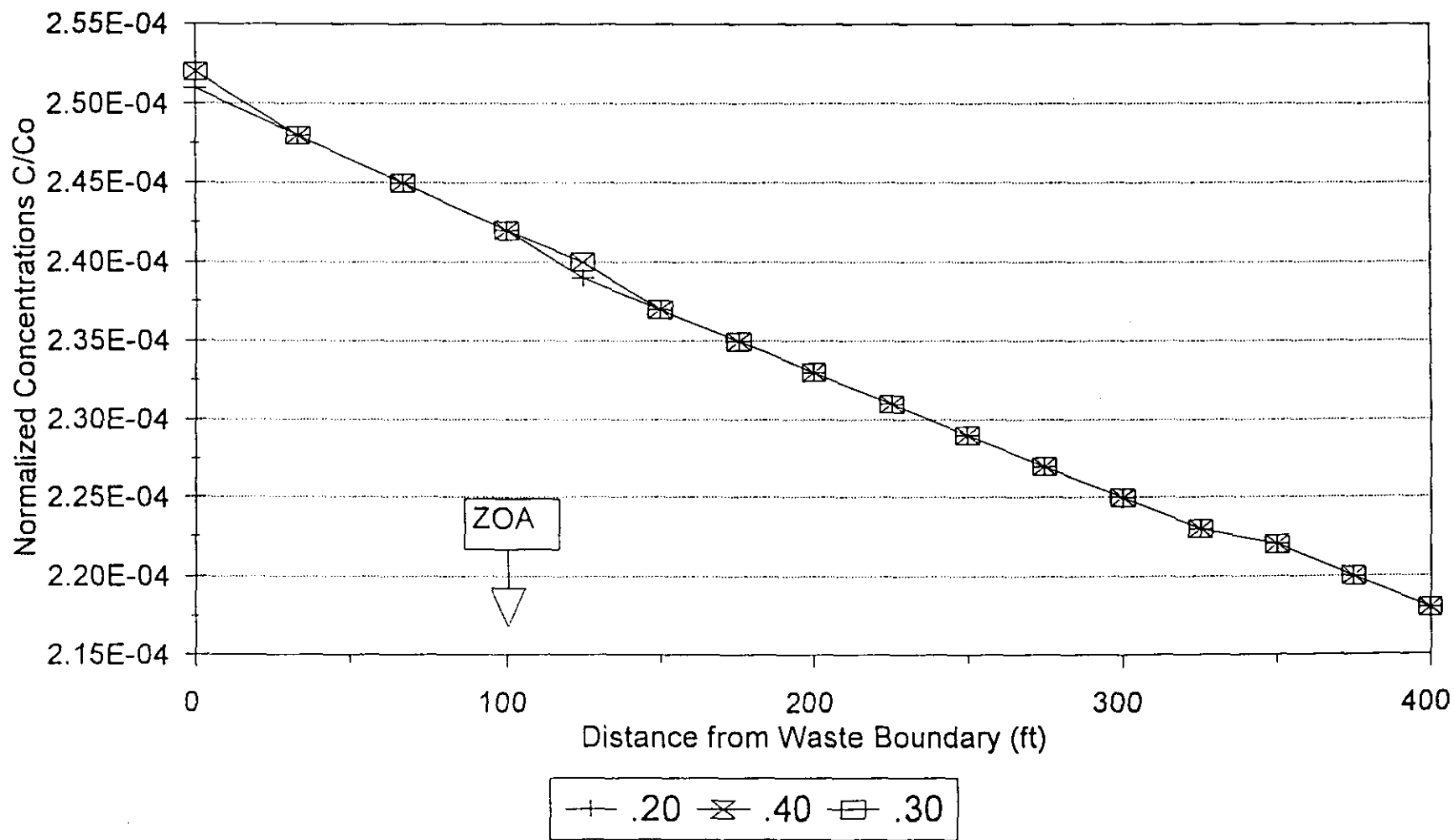


Figure 3.20. Concentration versus distance at 100 years as a function of porosity.



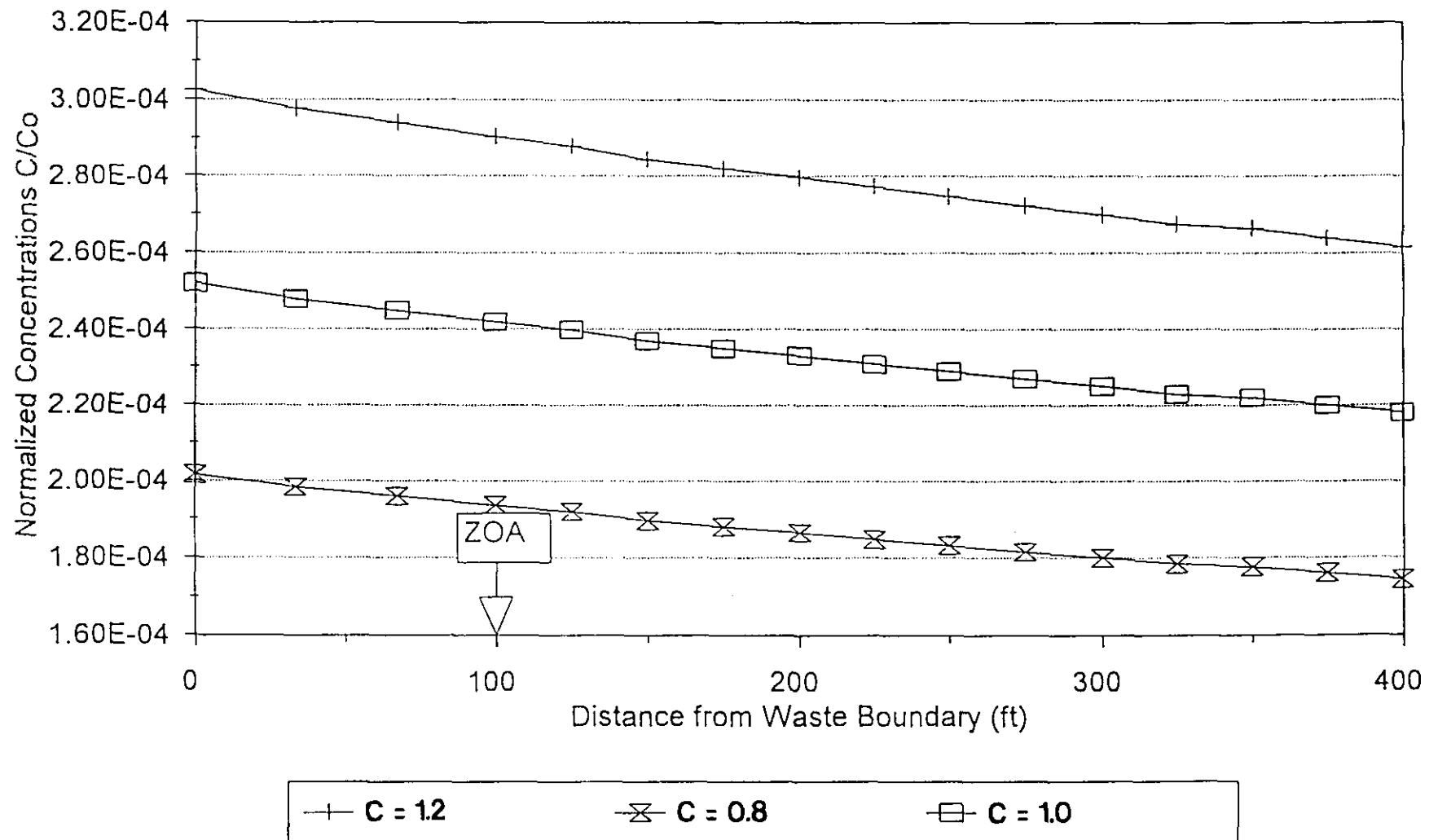


Figure 3.21. Concentration versus distance at 100 years as a function of leachate concentration.

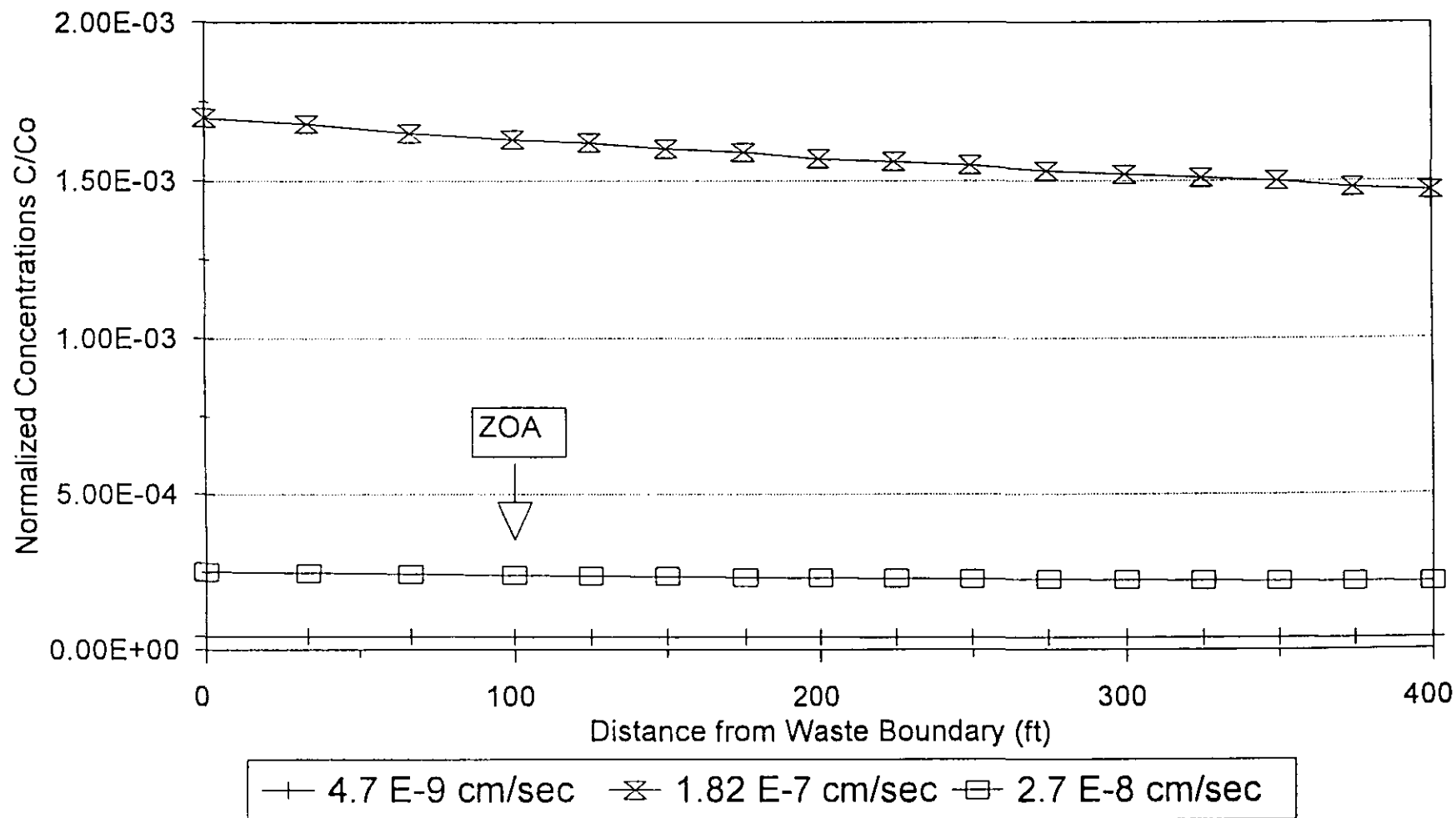


Figure 3.22. Concentration versus distance at 100 years as a function of liner conductivity.

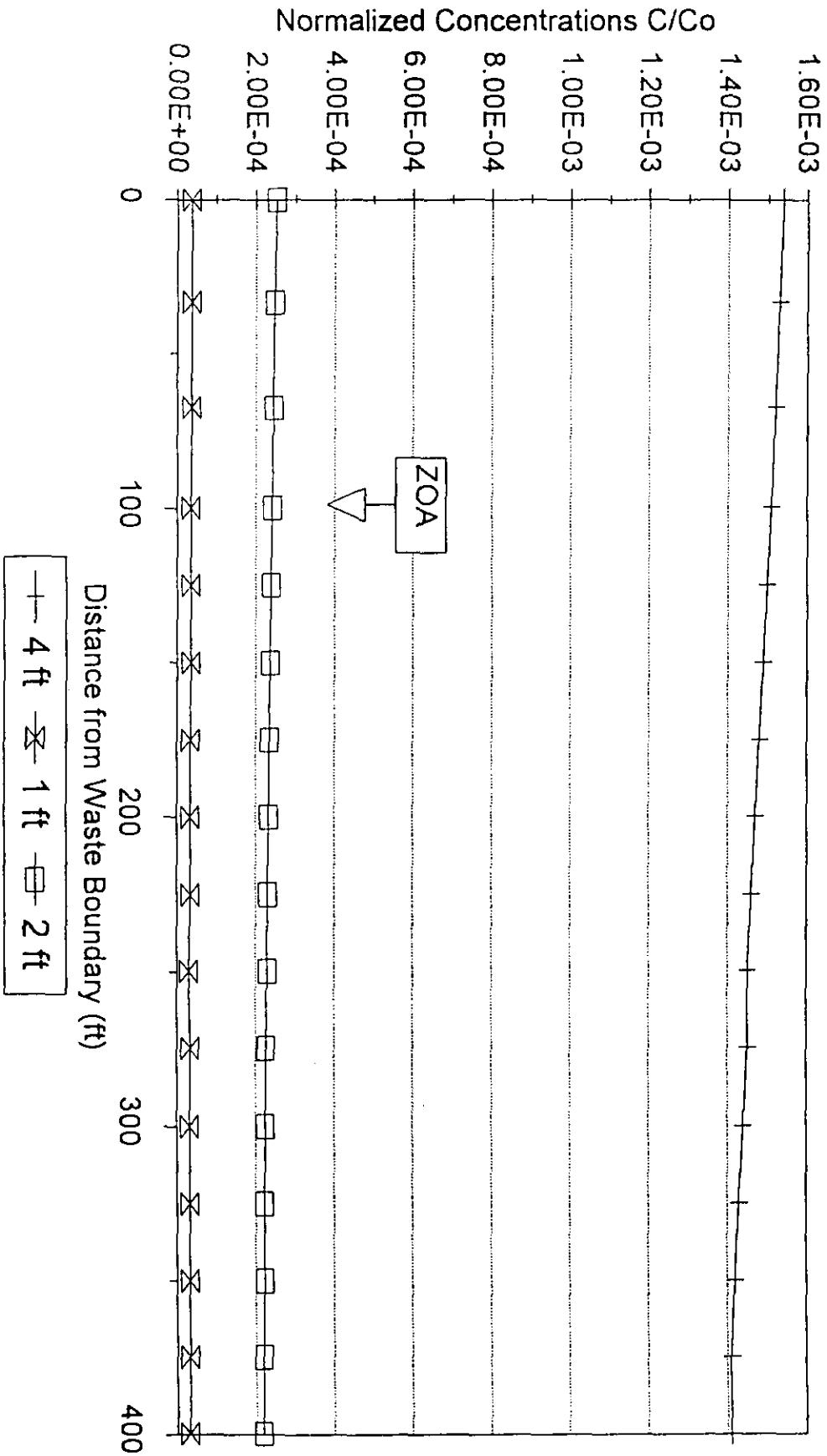


Figure 3.23. Concentration versus distance at 100 years as a function of leachate head.

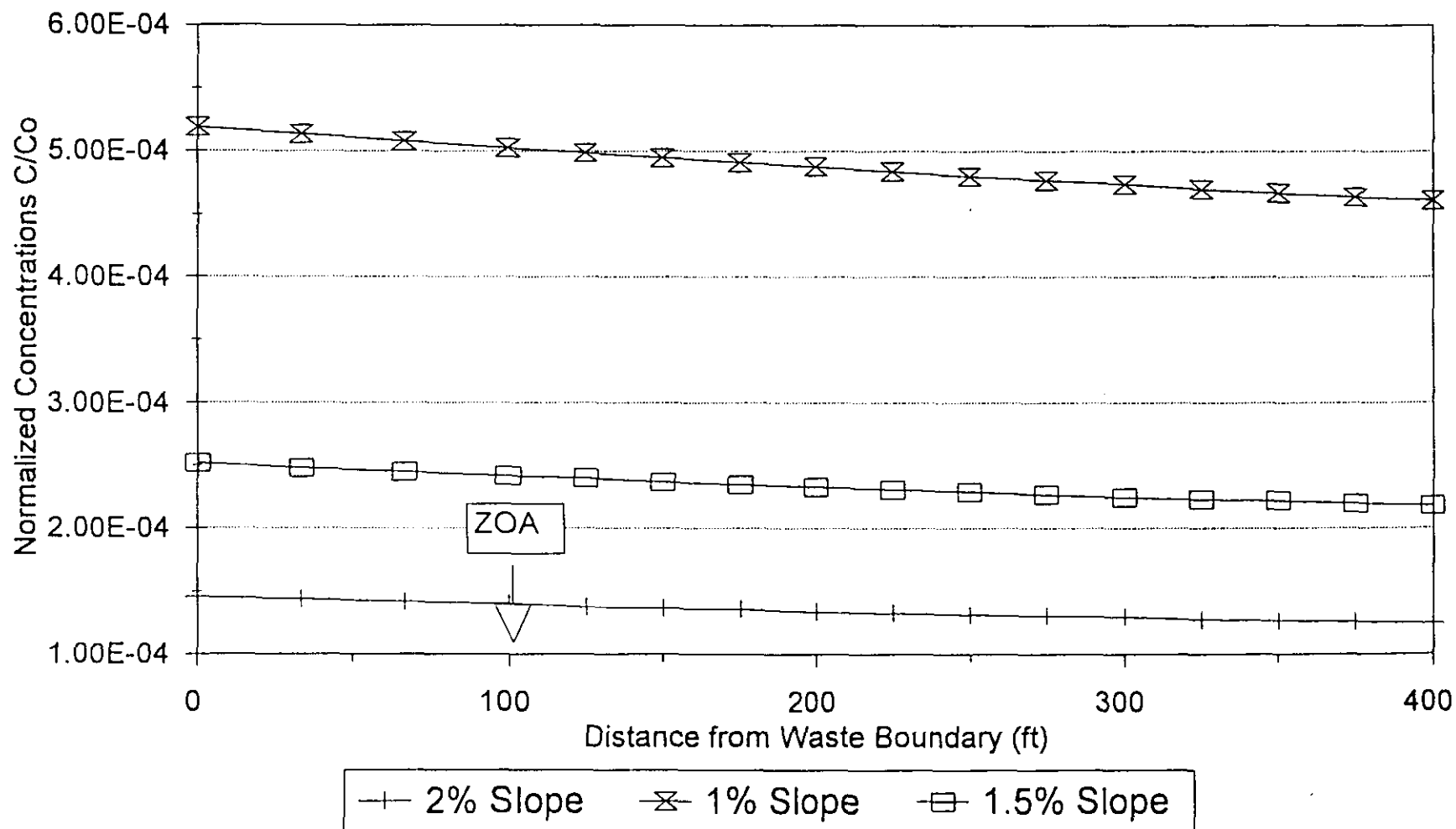


Figure 3.24. Concentration versus distance at 100 years as a function of invert slope.

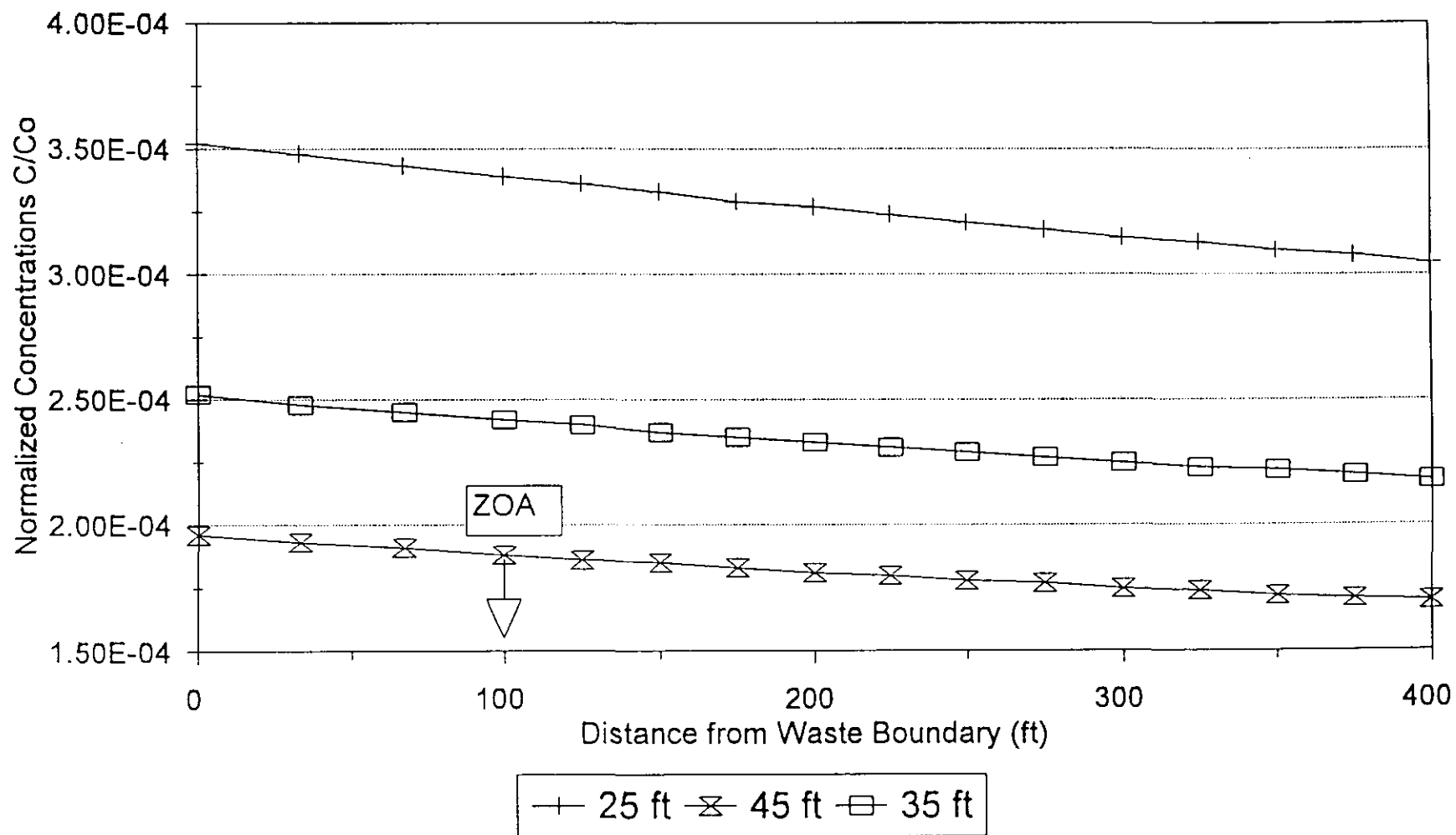


Figure 3.25. Concentration versus distance at 100 years as a function of aquifer thickness.

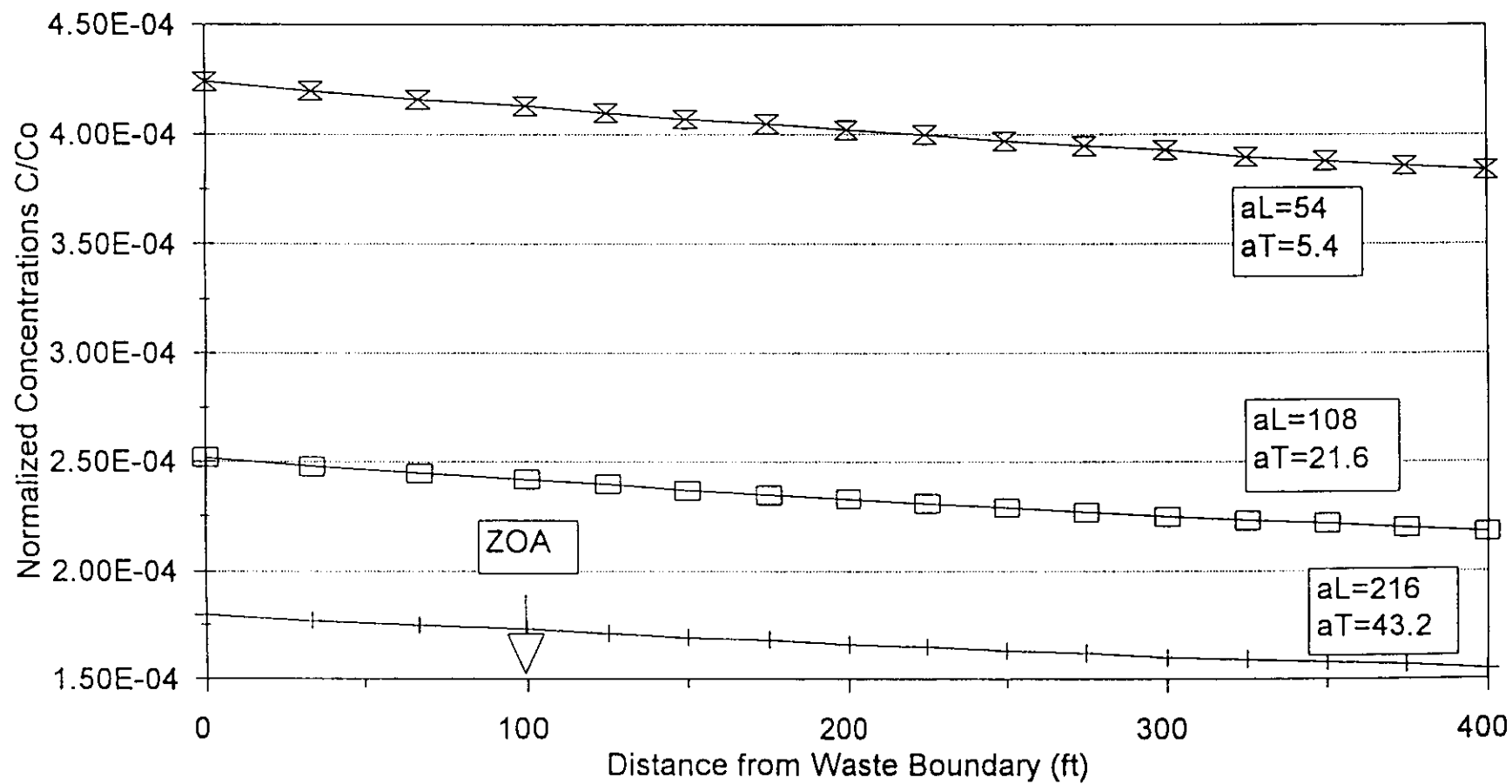


Figure 3.26. Concentration versus distance at 100 years as a function of dispersivity.

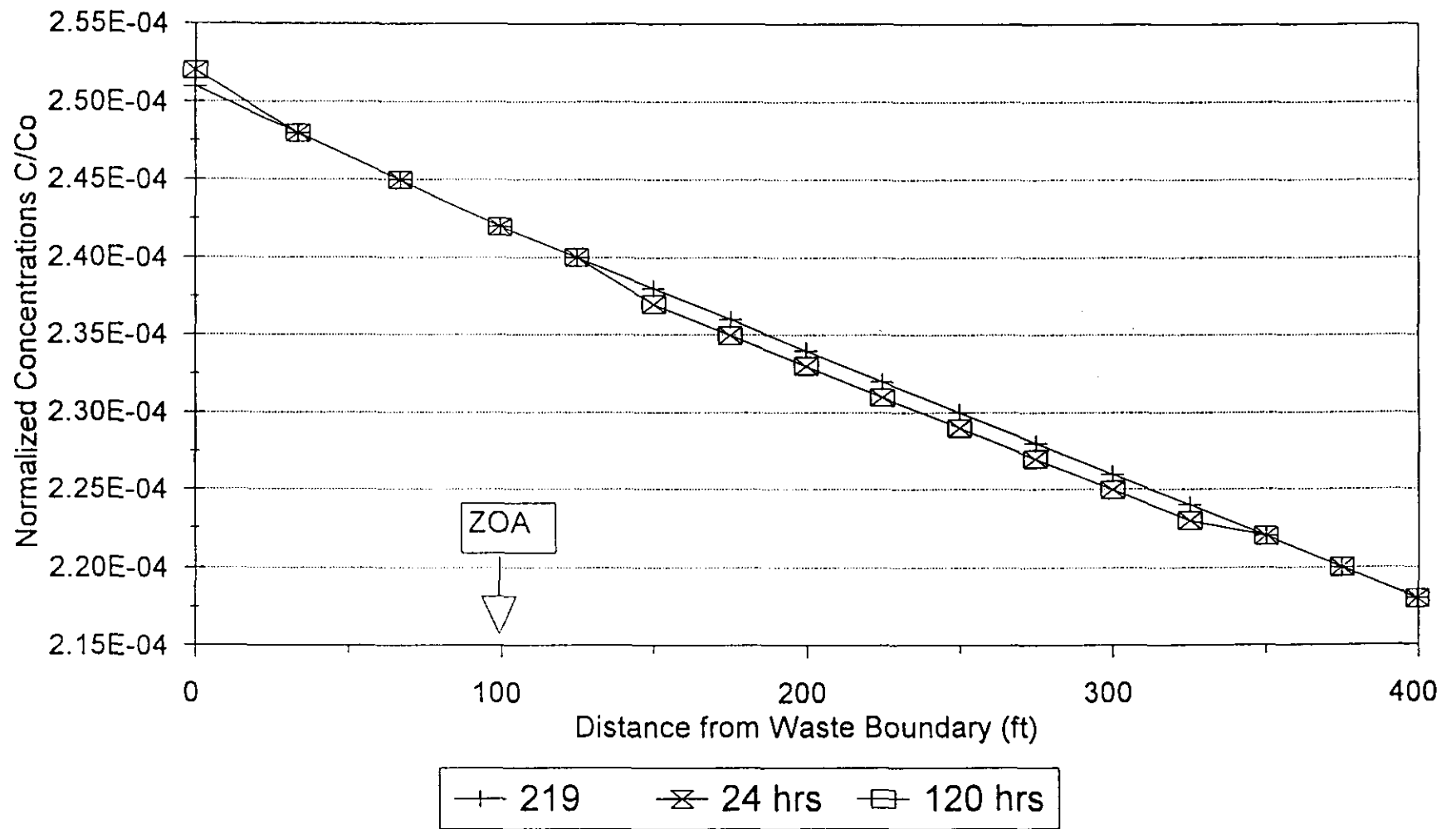


Figure 3.27. Concentration versus distance at 100 years as a function of time step.

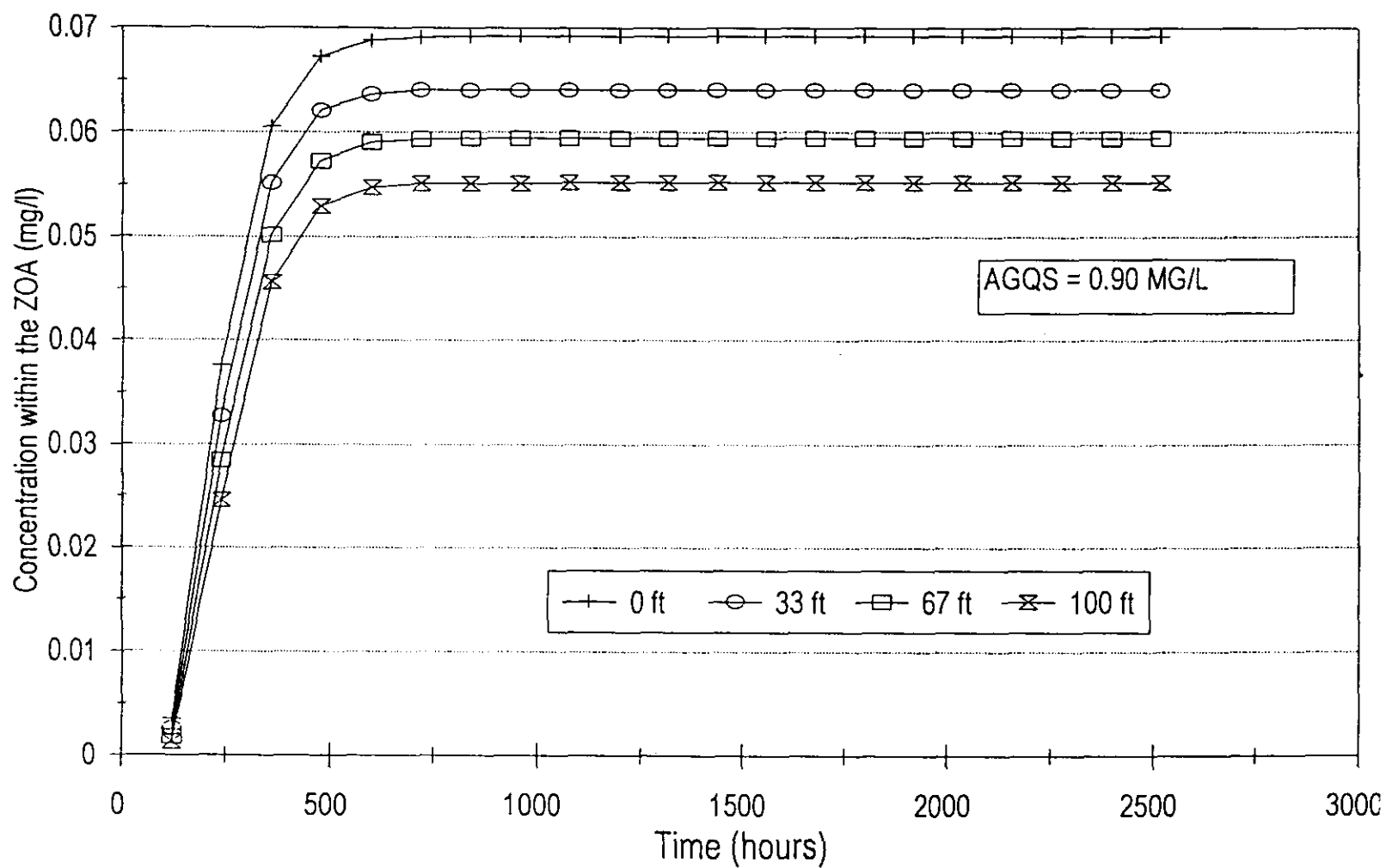


Figure 3.28. Concentration of ammonia in the ZOA as a function of time.



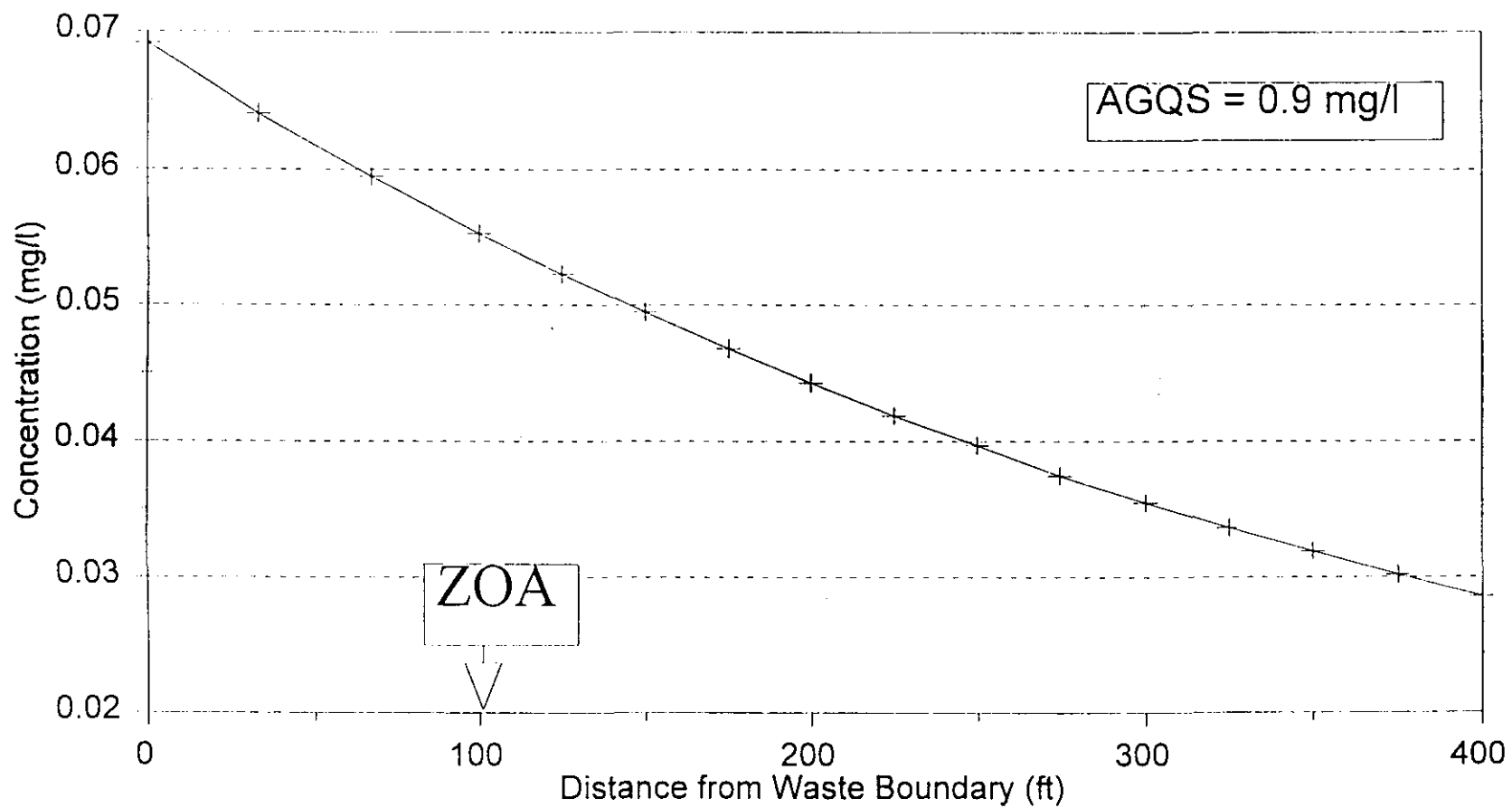


Figure 3.29. Concentration of ammonia at 100 years versus distance.

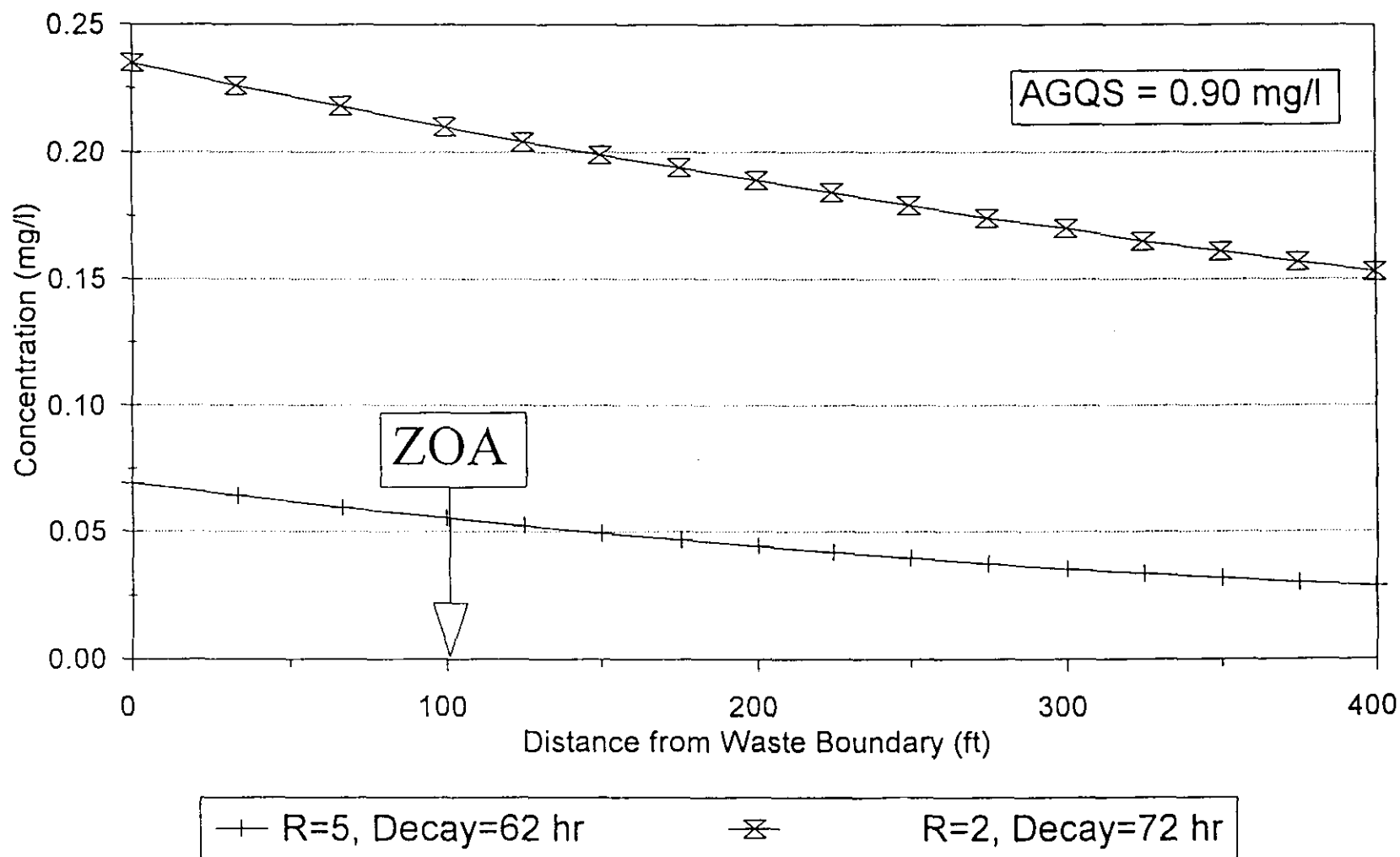


Figure 3.30. Concentration versus distance at 100 years for ammonia as a function of retardation and biodegradation.

Table 2.1. Summary of model input parameters.

| Parameter                                                                                         | Site Specific Value or Estimated Range                                                              | Model Value (Base Case)                                                                                   | Reference                                                    |
|---------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------|--------------------------------------------------------------|
| Hydraulic Conductivity*                                                                           | 1500 ft/day                                                                                         | 1500 ft/day                                                                                               | Aquifer test at downgradient edge of ZOA                     |
| Porosity                                                                                          | 24.9 - 35.4 percent                                                                                 | 30 percent                                                                                                | Laboratory testing of site-specific soil samples             |
| Hydraulic Gradient*                                                                               | 0.003 - 0.009 ft/ft                                                                                 | 0.005 ft/ft                                                                                               | Potentiometric surface maps (7/94 - 4/95)                    |
| Longitudinal Dispersivity* ( $a_L$ )                                                              | 54 - 216 feet (5 - 20 percent of travel path)                                                       | 108 feet (10 percent of travel path)                                                                      | Pickens and Grisak 1981 WRR V.17 No. 4 Appendix C to LPC-PA2 |
| Transverse Dispersivity*                                                                          | 5.4 - 43.2 feet (20 percent of $a_L$ )                                                              | 21.6 feet (20 percent of $a_L$ )                                                                          | Appendix C to LPC-PA2                                        |
| Leachate Head                                                                                     | 2 feet                                                                                              | 2 feet                                                                                                    | Design Specification                                         |
| Source Area                                                                                       | 200 x 200 feet – 400 x 400 feet                                                                     | 267 x 267 feet                                                                                            | Design specification with 1.5% invert slope and 2-foot head  |
| Liner Thickness                                                                                   | 2 inches minimum                                                                                    | 2 inches                                                                                                  | Design Specification                                         |
| Liner Permeability                                                                                | $4.7 \times 10^{-9}$ - $1.82 \times 10^{-7}$ cm/sec                                                 | $2.7 \times 10^{-8}$ cm/sec (geometric mean of data)                                                      | Chicago Testing Lab., Inc. of actual liner material          |
| Uppermost Aquifer Saturated Thickness*                                                            | 25 - 45 feet                                                                                        | 35 feet                                                                                                   | Report of Hydrogeological Investigations (GeoTrans, 1995a)   |
| Constituent Source Concentration $C/C_o$ (used mean plus 2 std. dev. e.g., chloride: 4940.5 mg/L) | Observed range of leachate data. For example, chloride leachate data ranged from 2110 to 4370 mg/L. | 1 mg/L (normalized value) (multiply by the $C_o$ for each constituent to obtain its source concentration) | Leachate sampling data (Appendix C)                          |
| Ammonia Half-Life*                                                                                | 23 - 72 days                                                                                        | 62 days                                                                                                   | Andreoli et al., 1979; J. WPCF 51:841-854                    |
| Ammonia Retardation*                                                                              | 2 - 80                                                                                              | 5                                                                                                         | Drever, 1988<br>Ceazan et al., 1989; ES&T Vol. 23, No. 11    |

\* Value updated since previous submittal (July 1994) based on recent detailed studies.

Table 2.2. Detectable leachate constituent concentrations.

| Parameter                   | Leachate Sample Analysis (mg/L) |        |        |        | Model        |
|-----------------------------|---------------------------------|--------|--------|--------|--------------|
|                             | West Sump                       | N1     | G7     | 0      | Leachate     |
|                             |                                 |        |        |        | Conc. (mg/L) |
| alkalinity                  | 8180                            | 5650   | 5350   | 4860   | 8975.7152    |
| specific conductance*       | 1496                            | 1993   | 1330   | 1901   | 2315.7840    |
| aluminum                    | 0.4                             | 0.57   | 0.09   | 0.12   | 0.7559       |
| ammonia                     | 1420                            | 1380   | 1280   | 1880   | 2023.1666    |
| antimony                    | 0.01                            | 0.01   | 0.01   | 0.01   | 0.0100       |
| arsenic                     | 0.061                           | 0.005  | 0.005  | 0.005  | 0.0750       |
| barium                      | 0.6                             | 0.54   | 0.17   | 0.19   | 0.8283       |
| beryllium                   | 0.001                           | 0.001  | 0.001  | 0.001  | 0.0010       |
| boron                       | 17.5                            | 4.67   | 4.72   | 4.64   | 20.7060      |
| cadmium                     | 0.001                           | 0.0007 | 0      | 0.0004 | 0.0012       |
| calcium                     | 47.6                            | 80     | 31.4   | 82.1   | 110.0723     |
| chloride                    | 4370                            | 2480   | 2110   | 2870   | 4940.4523    |
| chromium                    | 0.68                            | 0.14   | 0.18   | 0.18   | 0.8097       |
| cobalt                      | 0.08                            | 0.04   | 0.03   | 0.05   | 0.0932       |
| copper                      | 0.02                            | 0.04   | 0.01   | 0.01   | 0.0483       |
| cyanide                     | 0.079                           | 0.039  | 0.013  | 0.029  | 0.0962       |
| fluoride                    | 0.27                            | 0.16   | 0.18   | 0.34   | 0.4043       |
| iron                        | 5.58                            | 16.5   | 5.32   | 2.75   | 19.7575      |
| lead                        | 0.026                           | 0.022  | 0.0075 | 0.0075 | 0.0351       |
| magnesium                   | 113                             | 135    | 147    | 115    | 160.2210     |
| manganese                   | 0.08                            | 0.12   | 0.05   | 0.18   | 0.2199       |
| mercury                     | 0.001                           | 0.001  | 0.001  | 0.001  | 0.0010       |
| nickel                      | 0.55                            | 0.31   | 0.34   | 0.46   | 0.6368       |
| nitrate/ite                 | 0.01                            | 0.01   | 0.01   | 0.21   | 0.2600       |
| potassium                   | 790                             | 842    | 827    | 814    | 862.3219     |
| selenium                    | 0.01                            | 0.01   | 0.01   | 0.01   | 0.0100       |
| silver                      | 0.005                           | 0.005  | 0.005  | 0.005  | 0.0050       |
| sodium                      | 2000                            | 856    | 774    | 1150   | 2315.8402    |
| sulfate                     | 25                              | 50     | 25     | 25     | 56.2500      |
| thallium                    | 0.005                           | 0.005  | 0.005  | 0.005  | 0.0050       |
| tin                         | 0.21                            | 0.1    | 0.21   | 0.1    | 0.2820       |
| vanadium                    | 0.09                            | 0.03   | 0.02   | 0.02   | 0.1073       |
| zinc                        | 0.32                            | 0.12   | 0.03   | 0.03   | 0.3985       |
| acetone                     | 0.084                           | 0.045  | 0.015  | 0.022  | 0.1037       |
| benzene                     | 0.003                           | 0.0025 | 0.0025 | 0.0025 | 0.0025       |
| benzoic acid                | 0.58                            | 0.25   | 0.027  | 0.028  | 0.7436       |
| 1,4 dichlorobenzene         | 0.024                           | 0.006  | 0.01   | 0.009  | 0.0283       |
| cis 1,2-DCE                 | 0.003                           | 0.0025 | 0.0025 | 0.0025 | 0.0025       |
| 2,4-dimethylphenol          | 0.03                            | 0.05   | 0.086  | 0.28   | 0.3409       |
| ethylbenzene                | 0.042                           | 0.034  | 0.023  | 0.023  | 0.0490       |
| bis(2-ethylhexyl)phthalate  | 0.049                           | 0.13   | 0.02   | 0.014  | 0.1601       |
| p-isopropyltoluene (cymene) | 0.028                           | 0.019  | 0.016  | 0.0025 | 0.0375       |
| mek 2-butanone              | 0.003                           | 0.0025 | 0.0025 | 0.0025 | 0.0025       |
| 4-methyl-2-pentanone (MIBK) | 0.019                           | 0.005  | 0.005  | 0.005  | 0.0225       |

Table 2.2. Detectable leachate constituent concentrations (continued).

| Parameter              | Leachate Sample Analysis (mg/L) |        |        |         | Model        |
|------------------------|---------------------------------|--------|--------|---------|--------------|
|                        | West Sump                       | N1     | G7     | 0       | Leachate     |
|                        |                                 |        |        |         | Conc. (mg/L) |
| 3&4-methylphenol       | 0.05                            | 0.05   | 0.0055 | 0.0055  | 0.0791       |
| naphthalene            | 0.051                           | 0.05   | 0.021  | 0.0055  | 0.0767       |
| phenol                 | 0.006                           | 0.05   | 0.0055 | 0.0055  | 0.0611       |
| pcb-1242               | 0.003                           | 0.0003 | 0      | 0.00025 | 0.0031       |
| n-propylbenzene        | 0.005                           | 0.0025 | 0.0025 | 0.0025  | 0.0056       |
| phenanthrene           | 0.018                           | 0.05   | 0.0055 | 0.0055  | 0.0618       |
| 1,2,4-trimethylbenzene | 0.041                           | 0.014  | 0.015  | 0.012   | 0.0479       |
| tetrahydrofuran        | 1                               | 0.51   | 0.74   | 0.19    | 1.2984       |
| toluene                | 0.099                           | 0.026  | 0.016  | 0.018   | 0.1192       |
| 1,3,5-trimethylbenzene | 0.016                           | 0.005  | 0.006  | 0.005   | 0.0187       |
| vinyl chloride         | 0.01                            | 0.001  | 0.012  | 0.022   | 0.0285       |
| xylene                 | 0.13                            | 0.1    | 0.076  | 0.08    | 0.1459       |

\*Specific conductance (umohs) leachate data is from four groups of five-well composites (April 27, 1992).

Table 3.1. Leachate constituent surrogate groups.

| Model<br>Leachate AGQS |              |         | Model<br>Leachate AGQS      |              |        |
|------------------------|--------------|---------|-----------------------------|--------------|--------|
| Parameter              | Conc. (mg/l) | (mg/l)  | Parameter                   | Conc. (mg/l) | (mg/l) |
| ammonia                | 2023.1666    | 0.9     | Organic Surrogate           |              |        |
| chloride               | 4940.4523    | 87.51   | acetone                     | 0.1037       | 0.01   |
| alkalinity             | 8975.7152    | 1522.98 | benzene                     | 0.0025       | 0.0028 |
| mercury                | 0.0010       | 0.0002  | 1,4 dichlorobenzene         | 0.0283       | 0.0037 |
| Boron Surrogate        |              |         | cis 1,2-DCE                 | 0.0025       | 0.15   |
| aluminum               | 0.7559       | 1.21    | 2,4-dimethylphenol          | 0.3409       | 0.1    |
| barium                 | 0.8283       | 0.224   | ethylbenzene                | 0.0490       | 0.005  |
| boron                  | 20.7060      | 0.098   | bis(2-ethylhexyl)phthalate  | 0.1601       | 0.072  |
| iron                   | 19.7575      | 4.53    | p-isopropyltoluene (cymene) | 0.0375       | 0.005  |
| benzoic acid           | 0.7436       | 0.5     | mek 2-butanone              | 0.0025       | 0.005  |
| Nitrate Surrogate      |              |         | 4-methyl-2-pentanone (MIBK) | 0.0225       | 0.01   |
| calcium                | 110.0723     | 428.889 | 3&4-methylphenol            | 0.0791       | 0.1    |
| magnesium              | 160.2210     | 109.109 | naphthalene                 | 0.0767       | 0.1    |
| potassium              | 862.3219     | 28.194  | phenol                      | 0.0611       | 0.1    |
| nitrate/ite            | 0.2600       | 11.7389 | pcb-1242                    | 0.0031       | 0.0025 |
| sodium                 | 2315.8402    | 93.02   | n-propylbenzene             | 0.0056       | 0.005  |
| sulfate                | 56.2500      | 179.373 | phenanthrene                | 0.0618       | 0.1    |
| zinc                   | 0.3985       | 622.283 | 1,2,4-tmb                   | 0.0479       | 0.005  |
| Nickel Surrogate       |              |         | tetrahydrofuran             | 1.2984       | 0.042  |
| chromium               | 0.8097       | 0.1     | toluene                     | 0.1192       | 0.02   |
| nickel                 | 0.6368       | 0.04    | 1,3,5-trimethylbenzene      | 0.0187       | 0.005  |
| Selenium Surrogate     |              |         | vinyl chloride              | 0.0285       | 0.017  |
| antimony               | 0.0100       | 0.25    | xylene                      | 0.1459       | 0.005  |
| arsenic                | 0.0750       | 0.002   | 1,2-dichloropropane         | 0.0025       | 0.006  |
| beryllium              | 0.0010       | 0.005   | trichloroethene             | 0.0025       | 0.066  |
| cadmium                | 0.0012       | 0.005   | 2-hexanone                  | 0.005        | 0.01   |
| cobalt                 | 0.0932       | 0.1     | tetrachloroethene           | 0.0025       | 0.026  |
| copper                 | 0.0483       | 0.02    | chlorobenzene               | 0.0025       | 0.005  |
| cyanide                | 0.0962       | 0.034   | styrene                     | 0.005        | 0.01   |
| fluoride               | 0.4043       | 0.2734  | chloroform                  | 0.0025       | 0.005  |
| lead                   | 0.0351       | 0.004   | 1,1,1-trichloroethane       | 0.0025       | 0.012  |
| manganese              | 0.2199       | 1.4795  | chloroethane                | 0.005        | 0.01   |
| selenium               | 0.0100       | 0.002   | methylene chloride          | 0.0025       | 0.008  |
| silver                 | 0.0050       | 0.01    | carbon disulfide            | 0.0025       | 0.005  |
| thallium               | 0.0050       | 0.2     | 1,1-dichloroethene          | 0.0025       | 0.0025 |
| tin                    | 0.2820       | 0.1     | 1,1-dichloroethane          | 0.0025       | 0.031  |
| vanadium               | 0.1073       | 0.05    | 1,2-dichloroethene, total   | 0.0025       | 0.115  |

Table 3.2. Concentration (mg/L) of surrogates at the downgradient edge of the ZOA.

| Parameter          | Model<br>Leachate<br>Conc. (mg/L) | Normalized<br>Concentration<br>at ZOA | Concentration<br>at ZOA<br>(mg/L) | AGQS<br>(mg/L) |
|--------------------|-----------------------------------|---------------------------------------|-----------------------------------|----------------|
| chloride           | 4940.4523                         | 2.42e-04                              | 1.1956                            | 90.126         |
| mercury            | 0.0010                            | 2.42e-04                              | 2.42e-07                          | 0.0002         |
| Boron Surrogate    | 20.706                            | 2.42e-04                              | 0.0050                            | 0.098          |
| Nitrate Surrogate  | 2315.8402                         | 2.42e-04                              | 0.5604                            | 11.7389        |
| Nickel Surrogate   | 0.8097                            | 2.42e-04                              | 0.0002                            | 0.8097         |
| Selenium Surrogate | 0.4043                            | 2.42e-04                              | 0.0001                            | 0.002          |
| Organic Surrogate  | 0.3409                            | 2.42e-04                              | 0.0001                            | 0.0025         |
| Ammonia            | 2023.0000                         | 2.42e-04                              | 0.4900                            | 0.9            |

Table 3.3. Sensitivity analysis parameter values.

| Sensitivity Run | Parameter Change                                        |
|-----------------|---------------------------------------------------------|
| Run 80          | Baseline Run                                            |
| Run 81          | Low K = 100 ft/day                                      |
| Run 82          | High K = 3000 ft/day                                    |
| Run 83          | Low Gradient = 0.003 ft/ft                              |
| Run 84          | High Gradient = 0.009 ft/ft                             |
| Run 85          | Low Porosity = 0.20                                     |
| Run 86          | High Porosity = 0.40                                    |
| Run 87          | Low Thickness = 25 feet                                 |
| Run 88          | High Thickness = 45 feet                                |
| Run 89          | Low Dispersion $a_L = 54$ feet<br>$a_T = 5.4$ feet      |
| Run 90          | High Dispersion $a_L = 216$ feet<br>$a_T = 43.2$ feet   |
| Run 91          | 36500 time steps at 24 hours each                       |
| Run 92          | 4000 time steps at 219 hours each                       |
| Run 93          | Liner K = $1.82 \times 10^{-7}$ cm/sec.                 |
| Run 94          | Liner K = $4.7 \times 10^{-9}$ cm/sec.                  |
| Run 95          | Invert Slope = 1%<br>Source Area = 400 x 400 feet       |
| Run 96          | Invert Slope = 2%<br>Source Area = 200 x 200 feet       |
| Run 97          | Leachate Head = 1 foot<br>Source Area = 133 x 133 feet  |
| Run 98          | Leachate Head = 4 feet<br>Source Area = 533 x 533 feet  |
| Run 99A         | Ammonia with R5 = Half-life = 62 days                   |
| Run 99B         | Ammonia with R=2, Half-life = 72 days                   |
| Run 100         | Ammonia with R=2, Half-life = 72 days, and K=100 ft/day |



Table 3.4. Surrogate concentrations at the ZOA edge as a function of sensitivity.

|                         |                             | Chloride                    | Mercury  | Boron Surrogate | Nitrate Surrogate | Nickel Surrogate | Selenium Surrogate | Organics Surrogate | Ammonia   |
|-------------------------|-----------------------------|-----------------------------|----------|-----------------|-------------------|------------------|--------------------|--------------------|-----------|
|                         | AGQS (mg/L)                 | 8.75E+01                    | 2.00E-04 | 9.80E-02        | 1.17E+01          | 8.10E-01         | 2.00E-03           | 2.50E-03           | 9.00E-01  |
|                         | Model Leachate Conc. (mg/L) | 8975.7150                   | 0.0010   | 20.706          | 2315.8402         | 0.8097           | 0.4043             | 0.3409             | 2023.1666 |
|                         |                             |                             |          |                 |                   |                  |                    |                    |           |
| RUN                     | Normalized Conc. at ZOA     | CONCENTRATION AT ZOA (mg/L) |          |                 |                   |                  |                    |                    |           |
| Basecase                | 2.42E-04                    | 2.17E+00                    | 2.42E-07 | 5.01E-03        | 5.60E-01          | 1.96E-04         | 9.78E-05           | 8.25E-05           | 4.90E-01  |
| K = 100 ft/day          | 3.63E-03                    | 3.26E+01                    | 3.63E-06 | 7.52E-02        | 8.41E+00          | 2.94E-03         | 1.47E-03           | 1.24E-03           | 7.34E+00  |
| K = 3000 ft/day         | 1.21E-04                    | 1.09E+00                    | 1.21E-07 | 2.51E-03        | 2.80E-01          | 9.80E-05         | 4.89E-05           | 4.12E-05           | 2.45E-01  |
| i = 0.003               | 4.03E-04                    | 3.62E+00                    | 4.03E-07 | 8.34E-03        | 9.33E-01          | 3.26E-04         | 1.63E-04           | 1.37E-04           | 8.15E-01  |
| i = 0.009               | 1.35E-04                    | 1.21E+00                    | 1.35E-07 | 2.80E-03        | 3.13E-01          | 1.09E-04         | 5.46E-05           | 4.60E-05           | 2.73E-01  |
| n = 0.2                 | 2.42E-04                    | 2.17E+00                    | 2.42E-07 | 5.01E-03        | 5.60E-01          | 1.96E-04         | 9.78E-05           | 8.25E-05           | 4.90E-01  |
| n = 0.4                 | 2.42E-04                    | 2.17E+00                    | 2.42E-07 | 5.01E-03        | 5.60E-01          | 1.96E-04         | 9.78E-05           | 8.25E-05           | 4.90E-01  |
| 25 ft thick             | 3.39E-04                    | 3.04E+00                    | 3.39E-07 | 7.02E-03        | 7.85E-01          | 2.74E-04         | 1.37E-04           | 1.16E-04           | 6.86E-01  |
| 45 ft thick             | 1.85E-04                    | 1.66E+00                    | 1.85E-07 | 3.83E-03        | 4.28E-01          | 1.50E-04         | 7.48E-05           | 6.31E-05           | 3.74E-01  |
| Low Dispersivity        | 4.13E-04                    | 3.71E+00                    | 4.13E-07 | 8.55E-03        | 9.56E-01          | 3.34E-04         | 1.67E-04           | 1.41E-04           | 8.36E-01  |
| High Dispersivity       | 1.73E-04                    | 1.55E+00                    | 1.73E-07 | 3.58E-03        | 4.01E-01          | 1.40E-04         | 6.99E-05           | 5.90E-05           | 3.50E-01  |
| Time steps = 24 hr      | 2.42E-04                    | 2.17E+00                    | 2.42E-07 | 5.01E-03        | 5.60E-01          | 1.96E-04         | 9.78E-05           | 8.25E-05           | 4.90E-01  |
| Time steps = 219 hr     | 2.42E-04                    | 2.17E+00                    | 2.42E-07 | 5.01E-03        | 5.60E-01          | 1.96E-04         | 9.78E-05           | 8.25E-05           | 4.90E-01  |
| Liner K (1.82E-7 cm/s)  | 1.63E-03                    | 1.46E+01                    | 1.63E-06 | 3.38E-02        | 3.77E+00          | 1.32E-03         | 6.59E-04           | 5.56E-04           | 3.30E+00  |
| Liner K (4.79E-9 cm/s)  | 4.21E-05                    | 3.78E-01                    | 4.21E-08 | 8.72E-04        | 9.75E-02          | 3.41E-05         | 1.70E-05           | 1.44E-05           | 8.52E-02  |
| Invert slope = 1%       | 5.03E-04                    | 4.51E+00                    | 5.03E-07 | 1.04E-02        | 1.16E+00          | 4.07E-04         | 2.03E-04           | 1.71E-04           | 1.02E+00  |
| Invert slope = 2%       | 1.40E-04                    | 1.26E+00                    | 1.40E-07 | 2.90E-03        | 3.24E-01          | 1.13E-04         | 5.66E-05           | 4.77E-05           | 2.83E-01  |
| Head = 1 ft             | 3.61E-05                    | 3.24E-01                    | 3.61E-08 | 7.47E-04        | 8.36E-02          | 2.92E-05         | 1.46E-05           | 1.23E-05           | 7.30E-02  |
| Head = 4 ft             | 1.51E-03                    | 1.36E+01                    | 1.51E-06 | 3.13E-02        | 3.50E+00          | 1.22E-03         | 6.11E-04           | 5.15E-04           | 3.05E+00  |
| Concentration (C = 1.2) | 2.90E-04                    | 2.61E+00                    | 2.90E-07 | 6.01E-03        | 6.73E-01          | 2.35E-04         | 1.17E-04           | 9.90E-05           | 5.88E-01  |
| Concentration (C = 0.8) | 1.94E-04                    | 1.74E+00                    | 1.94E-07 | 4.01E-03        | 4.48E-01          | 1.57E-04         | 7.83E-05           | 6.60E-05           | 3.92E-01  |
| R = 5, Half Life = 62 d |                             |                             |          |                 |                   |                  |                    |                    | 5.50E-02  |
| R=2, Half Life=72 d     |                             |                             |          |                 |                   |                  |                    |                    | 2.10E-01  |
| R=2, HL = 72 d, K=100   |                             |                             |          |                 |                   |                  |                    |                    | 3.66E-03  |

Table 3.5 MAPC concentrations (µg/L) in verification and detection wells.

| Parameter                                      | Leachate     | MAPC CONC. (ug/L) in Verification and Detection Wells |           |          |            |            |            |           |          |          |  |
|------------------------------------------------|--------------|-------------------------------------------------------|-----------|----------|------------|------------|------------|-----------|----------|----------|--|
|                                                | Conc. (ug/l) | G42                                                   | G38       | G41      | P3R, P4R   | G39        | G43        | G40       | B15P     | B15R     |  |
| Run: MAPC-1 Normalized Concentration           |              | 3.73E-03                                              | 2.67E-04  | 8.84E-05 | 1.50E-03   | 4.75E-03   | 3.31E-03   | 9.99E-04  | 9.61E-05 | 3.56E-05 |  |
| Aluminum (dis)                                 | 755.9        | 2.8195                                                | 0.2018    | 0.0668   | 1.1339     | 3.5905     | 2.5020     | 0.7551    | 0.0726   | 0.0269   |  |
| alkalinity                                     | 8975700      | 33479.3610                                            | 2396.5119 | 793.4519 | 13463.5500 | 42634.5750 | 29709.5670 | 8966.7243 | 862.5648 | 319.5349 |  |
| Ammonia                                        | 2023170      | 7546.4241                                             | 540.1864  | 178.8482 | 3034.7550  | 9610.0575  | 6696.6927  | 2021.1468 | 194.4266 | 72.0249  |  |
| Arsenic (dis)                                  | 75           | 0.2798                                                | 0.0200    | 0.0066   | 0.1125     | 0.3563     | 0.2483     | 0.0749    | 0.0072   | 0.0027   |  |
| Barium (dis)                                   | 828.3        | 3.0896                                                | 0.2212    | 0.0732   | 1.2425     | 3.9344     | 2.7417     | 0.8275    | 0.0796   | 0.0295   |  |
| Boron (dis)                                    | 20700        | 77.2110                                               | 5.5269    | 1.8299   | 31.0500    | 98.3250    | 68.5170    | 20.6793   | 1.9893   | 0.7369   |  |
| Cadmium (dis)                                  | 1.2          | 0.0045                                                | 0.0003    | 0.0001   | 0.0018     | 0.0057     | 0.0040     | 0.0012    | 0.0001   | 0.0000   |  |
| Calcium (dis)                                  | 110072.3     | 410.5697                                              | 29.3893   | 9.7304   | 165.1085   | 522.8434   | 364.3393   | 109.9622  | 10.5779  | 3.9186   |  |
| Chloride                                       | 4940500      | 18428.0650                                            | 1319.1135 | 436.7402 | 7410.7500  | 23467.3750 | 16353.0550 | 4935.5595 | 474.7821 | 175.8818 |  |
| Chromium (dis)                                 | 809.7        | 3.0202                                                | 0.2162    | 0.0716   | 1.2146     | 3.8461     | 2.6801     | 0.8089    | 0.0778   | 0.0288   |  |
| Cobalt (dis)                                   | 93.2         | 0.3476                                                | 0.0249    | 0.0082   | 0.1398     | 0.4427     | 0.3085     | 0.0931    | 0.0090   | 0.0033   |  |
| Copper (dis)                                   | 48.3         | 0.1802                                                | 0.0129    | 0.0043   | 0.0725     | 0.2294     | 0.1599     | 0.0483    | 0.0046   | 0.0017   |  |
| Cyanide (Total as Cn-)                         | 96.2         | 0.3588                                                | 0.0257    | 0.0085   | 0.1443     | 0.4569     | 0.3184     | 0.0961    | 0.0092   | 0.0034   |  |
| Fluoride (Total as F-)                         | 404.3        | 1.5080                                                | 0.1079    | 0.0357   | 0.6065     | 1.9204     | 1.3382     | 0.4039    | 0.0389   | 0.0144   |  |
| Iron (dis)                                     | 19757.5      | 73.6955                                               | 5.2753    | 1.7466   | 29.6363    | 93.8481    | 65.3973    | 19.7377   | 1.8987   | 0.7034   |  |
| Lead (disl)                                    | 35.1         | 0.1309                                                | 0.0094    | 0.0031   | 0.0527     | 0.1667     | 0.1162     | 0.0351    | 0.0034   | 0.0012   |  |
| Magnesium (dis)                                | 160220       | 597.6206                                              | 42.7787   | 14.1634  | 240.3300   | 761.0450   | 530.3282   | 160.0598  | 15.3971  | 5.7038   |  |
| Manganese (dis)                                | 219.9        | 0.8202                                                | 0.0587    | 0.0194   | 0.3299     | 1.0445     | 0.7279     | 0.2197    | 0.0211   | 0.0078   |  |
| Nickel (dis)                                   | 636.8        | 2.3753                                                | 0.1700    | 0.0583   | 0.9552     | 3.0248     | 2.1078     | 0.6362    | 0.0612   | 0.0227   |  |
| Nitrate (as Nitrogen)                          | 260          | 0.9698                                                | 0.0694    | 0.0230   | 0.3900     | 1.2350     | 0.8606     | 0.2597    | 0.0250   | 0.0093   |  |
| Potassium(dis)                                 | 862321.9     | 3216.4607                                             | 230.2399  | 76.2293  | 1293.4829  | 4096.0290  | 2854.2855  | 861.4596  | 82.8691  | 30.7777  |  |
| Silver (dis)                                   | 5            | 0.0187                                                | 0.0013    | 0.0004   | 0.0075     | 0.0238     | 0.0166     | 0.0050    | 0.0005   | 0.0001   |  |
| Sodium(dis)                                    | 2315840      | 8638.0832                                             | 618.3293  | 204.7203 | 3473.7600  | 11000.2400 | 7665.4304  | 2313.5242 | 222.5522 | 82.4439  |  |
| Tin (dis)                                      | 282          | 1.0519                                                | 0.0753    | 0.0249   | 0.4230     | 1.3395     | 0.9334     | 0.2817    | 0.0271   | 0.0100   |  |
| Vanadium (dis)                                 | 107.3        | 0.4002                                                | 0.0286    | 0.0095   | 0.1610     | 0.5097     | 0.3552     | 0.1072    | 0.0103   | 0.0038   |  |
| Zinc (dis)                                     | 398.5        | 1.4864                                                | 0.1064    | 0.0352   | 0.5978     | 1.8929     | 1.3190     | 0.3981    | 0.0383   | 0.0142   |  |
| mercury                                        | 1            | 0.0037                                                | 0.0003    | 0.0001   | 0.0015     | 0.0048     | 0.0033     | 0.0010    | 0.0001   | 0.0000   |  |
| sulfate                                        | 56250        | 209.8125                                              | 15.0188   | 4.9725   | 84.3750    | 267.1875   | 186.1875   | 56.1938   | 5.4056   | 2.0025   |  |
| antimony                                       | 10           | 0.0373                                                | 0.0027    | 0.0009   | 0.0150     | 0.0475     | 0.0331     | 0.0100    | 0.0010   | 0.0004   |  |
| beryllium                                      | 1            | 0.0037                                                | 0.0003    | 0.0001   | 0.0015     | 0.0048     | 0.0033     | 0.0010    | 0.0001   | 0.0000   |  |
| selenium                                       | 10           | 0.0373                                                | 0.0027    | 0.0009   | 0.0150     | 0.0475     | 0.0331     | 0.0100    | 0.0010   | 0.0004   |  |
| thallium                                       | 5            | 0.0187                                                | 0.0013    | 0.0004   | 0.0075     | 0.0238     | 0.0166     | 0.0050    | 0.0005   | 0.0002   |  |
| phenol                                         | 61.1         | 0.2279                                                | 0.0163    | 0.0054   | 0.0917     | 0.2902     | 0.2022     | 0.0610    | 0.0059   | 0.0022   |  |
| dichloropropane, 1,2-                          | 2.5          | 0.0093                                                | 0.0007    | 0.0002   | 0.0038     | 0.0119     | 0.0083     | 0.0025    | 0.0002   | 0.0001   |  |
| trichloroethene                                | 2.5          | 0.0093                                                | 0.0007    | 0.0002   | 0.0038     | 0.0119     | 0.0083     | 0.0025    | 0.0002   | 0.0001   |  |
| tetrachloroethene                              | 2.5          | 0.0093                                                | 0.0007    | 0.0002   | 0.0038     | 0.0119     | 0.0083     | 0.0025    | 0.0002   | 0.0001   |  |
| hexanone, 2-                                   | 5            | 0.0187                                                | 0.0013    | 0.0004   | 0.0075     | 0.0238     | 0.0166     | 0.0050    | 0.0005   | 0.0002   |  |
| chlorobenzene                                  | 2.5          | 0.0093                                                | 0.0007    | 0.0002   | 0.0038     | 0.0119     | 0.0083     | 0.0025    | 0.0002   | 0.0001   |  |
| styrene                                        | 5            | 0.0187                                                | 0.0013    | 0.0004   | 0.0075     | 0.0238     | 0.0166     | 0.0050    | 0.0005   | 0.0002   |  |
| chloroform                                     | 2.5          | 0.0093                                                | 0.0007    | 0.0002   | 0.0038     | 0.0119     | 0.0083     | 0.0025    | 0.0002   | 0.0001   |  |
| trichloroethane, 1,1,1-                        | 2.5          | 0.0093                                                | 0.0007    | 0.0002   | 0.0038     | 0.0119     | 0.0083     | 0.0025    | 0.0002   | 0.0001   |  |
| chloroethane                                   | 5            | 0.0187                                                | 0.0013    | 0.0004   | 0.0075     | 0.0238     | 0.0166     | 0.0050    | 0.0005   | 0.0002   |  |
| methylene chloride                             | 2.5          | 0.0093                                                | 0.0007    | 0.0002   | 0.0038     | 0.0119     | 0.0083     | 0.0025    | 0.0002   | 0.0001   |  |
| carbon disulfide                               | 2.5          | 0.0093                                                | 0.0007    | 0.0002   | 0.0038     | 0.0119     | 0.0083     | 0.0025    | 0.0002   | 0.0001   |  |
| dichloroethene, 1,1-                           | 2.5          | 0.0093                                                | 0.0007    | 0.0002   | 0.0038     | 0.0119     | 0.0083     | 0.0025    | 0.0002   | 0.0001   |  |
| dichloroethane, 1,1-                           | 2.5          | 0.0093                                                | 0.0007    | 0.0002   | 0.0038     | 0.0119     | 0.0083     | 0.0025    | 0.0002   | 0.0001   |  |
| dichloroethene, 1,2-, total                    | 2.5          | 0.0093                                                | 0.0007    | 0.0002   | 0.0038     | 0.0119     | 0.0083     | 0.0025    | 0.0002   | 0.0001   |  |
| Acetone;2-Propane                              | 310500       | 1158.1650                                             | 82.9035   | 27.4482  | 465.7500   | 1474.8750  | 1027.7550  | 310.1895  | 29.8391  | 11.0538  |  |
| Benzene*                                       | 6220         | 23.2006                                               | 1.6607    | 0.5498   | 9.3300     | 29.5450    | 20.5882    | 6.2138    | 0.5977   | 0.2214   |  |
| Benzoic Acid                                   | 297500       | 1109.6750                                             | 79.4325   | 26.2990  | 446.2500   | 1413.1250  | 984.7250   | 297.2025  | 28.5898  | 10.5910  |  |
| bis (2-Ethylhexyl) phthalate                   | 110650       | 412.7245                                              | 29.5436   | 9.7815   | 165.9750   | 525.5875   | 366.2515   | 110.5394  | 10.6335  | 3.9391   |  |
| Butanone, 2-; Methyl ethyl ketone; MEK         | 282000       | 1051.8600                                             | 75.2940   | 24.9288  | 423.0000   | 1339.5000  | 933.4200   | 281.7180  | 27.1002  | 10.0392  |  |
| Cresol, p-; cresol, 4-methylphenol             | 43000        | 160.3900                                              | 11.4810   | 3.8012   | 64.5000    | 204.2500   | 142.3300   | 42.9570   | 4.1323   | 1.5308   |  |
| Cymene; p-Isopropyltoluene, Dolicymene         | 18500        | 69.0050                                               | 4.9395    | 1.6354   | 27.7500    | 87.8750    | 61.2350    | 18.4815   | 1.7779   | 0.6586   |  |
| Dichlorobenzene, 1,4-; p-Dichlorobenzene       | 14570        | 54.3461                                               | 3.8902    | 1.2880   | 21.8550    | 69.2075    | 48.2267    | 14.5554   | 1.4002   | 0.5187   |  |
| Dichloroethylene, cis-1,2-                     | 7772         | 28.9896                                               | 2.0751    | 0.6870   | 11.6580    | 36.9170    | 25.7253    | 7.7642    | 0.7469   | 0.2767   |  |
| Dimethylphenol,2,4-                            | 124000       | 462.5200                                              | 33.1080   | 10.9616  | 186.0000   | 589.0000   | 410.4400   | 123.8760  | 11.9164  | 4.4144   |  |
| Ethylbenzene                                   | 24500        | 91.3850                                               | 6.5415    | 2.1658   | 36.7500    | 116.3750   | 81.0950    | 24.4755   | 2.3545   | 0.8722   |  |
| Methyl-2-pentanone, 4-; Methyl isobutyl ketone | 12300        | 45.8790                                               | 3.2841    | 1.0873   | 18.4500    | 58.4250    | 40.7130    | 12.2877   | 1.1820   | 0.4379   |  |
| Naphthalene                                    | 109150       | 407.1295                                              | 29.1431   | 9.6489   | 163.7250   | 518.4625   | 361.2865   | 109.0409  | 10.4893  | 3.8857   |  |
| PCBs; Polychlorinated biphenyls*               | 27600        | 102.9480                                              | 7.3692    | 2.4398   | 41.4000    | 131.1000   | 91.3560    | 27.5724   | 2.6524   | 0.9826   |  |
| Phenanthrene                                   | 35000        | 130.5500                                              | 9.3450    | 3.0940   | 52.5000    | 166.2500   | 115.8500   | 34.9650   | 3.3635   | 1.2480   |  |
| Propylbenzene, n-; 1-Phenylpropane             | 11000        | 41.0300                                               | 2.9370    | 0.9724   | 16.5000    | 52.2500    | 36.4100    | 10.9890   | 1.0571   | 0.3916   |  |
| Tetrahydrofuran; Tetramethylene oxide          | 748000       | 2790.0400                                             | 199.7160  | 66.1232  | 1122.0000  | 3553.0000  | 2475.8800  | 747.2520  | 71.8828  | 26.6288  |  |
| Toluene; Methylbenzene                         | 70950        | 264.6435                                              | 18.9437   | 6.2720   | 106.4250   | 337.0125   | 234.8445   | 70.8791   | 6.8183   | 2.5258   |  |
| Trimethylbenzene, 1,2,4-; Pseudocumene         | 14100        | 52.5930                                               | 3.7647    | 1.2464   | 21.1500    | 66.9750    | 46.6710    | 14.0859   | 1.3550   | 0.5020   |  |
| Trimethylbenzene, 1,3,5-; Mesitylene           | 11600        | 43.2680                                               | 3.0972    | 1.0254   | 17.4000    | 55.1000    | 38.3960    | 11.5884   | 1.1148   | 0.4130   |  |
| Vinyl chloride; Chloroethene*                  | 59300        | 221.1890                                              | 15.8331   | 5.2421   | 88.9500    | 281.6750   | 196.2830   | 59.2407   | 5.6987   | 2.1111   |  |
| Xylenes                                        | 101500       | 378.5950                                              | 27.1005   | 8.9726   | 152.2500   | 482.1250   | 335.9650   | 101.3985  | 9.7542   | 3.6134   |  |